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PROJECTED COAL DEVELOPMENT
CROW INDIAN RESERVATION

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Prepared by

Planning Support Group
Bureau of Indian Affairs
Department of the Interior
Billings, Montana

James F Canan

James F. Canan, Area Director

SUMMARY SHEET

SUMMARY

(x) Draft ( ) Final Environmental Statement

Department of the Interior
Bureau of Indian Affairs
Washington, D. C. 20240

1. Type of action: (x) Administrative ( ) Legislative

2. Brief description of action:

This programmatic statement covers the probable impact of two assumed levels of coal development on the Crow Indian Reservation and Ceded Area in Big Horn and Treasure Counties of Montana. The lower level projects the export of 20,000,000 tons of coal annually from three different mines. The upper level projects the mining of 90,000,000 tons per year at three mines plus three mining complexes, a portion of which will be utilized in three conversion plants on the reservation and Ceded Area.

3. Summary of environmental impacts on the Crow Resource

A. Population in the study area will increase
B. Employment and income levels will be increased
C. The socio-political structure will be altered
D. All service facilities as well as the transportation system will be impacted with some requiring substantial expansion and addition
E. Unsurveyed archeological and historical resources may be destroyed
F. Ambient air quality will be lowered at the high level and noise levels will increase.
G. The land surface may be altered both in use and productivity after reclamation
H. Vegetation will be destroyed by the mining activities and plant sites thus reducing livestock forage.
I. Soil structure and parent material will be disrupted and altered on the area to be strip mined
J. Scenic views will be altered and aesthetic values changed
K. Wildlife habitats will be altered or destroyed ; some populations will be destroyed or reduced while others may increase
L. Recreation use will be intensified
M. Water utilization and consumption will increase for mining and industrial uses
N. Valuable energy resources will be made available for utilization

4. Alternative considered
   A. No action (no further development)
   B. No development
   C. Alternative levels of development
   D. Defer development
   E. Modify lease terms
   F. Entrepreneurship
   G. Alternative source of Tribal Income
   H. Reclamation objectives
   I. Transportation methods
   J. Coal use
   K. Alternative supplies of coal
   L. Energy conservation alternatives

5. Review and coordination

Environmental Protection Agency
Federal Energy Administration
Atomic Energy Commission
Federal Power Commission
Department of the Army (Corps of Engineers)
Department of Health, Education & Welfare
Department of Labor
Clearing Houses for States of: Montana, Wyoming, North Dakota, South Dakota, Minnesota, Iowa, Wisconsin, and Illinois
Crow Tribal Council
Department of Commerce
Interstate Commerce Commission
Department of Transportation
U. S. Department of the Interior:
  Bureau of Land Management
  United States Geological Survey
  Bureau of Outdoor Recreation
  Fish and Wildlife Service
  Bureau of Reclamation
  Bureau of Mines
  National Park Service
  Mining Enforcement & Safety Administration

6. Date draft statement is made available to CEQ and the public:
January 16, 1975

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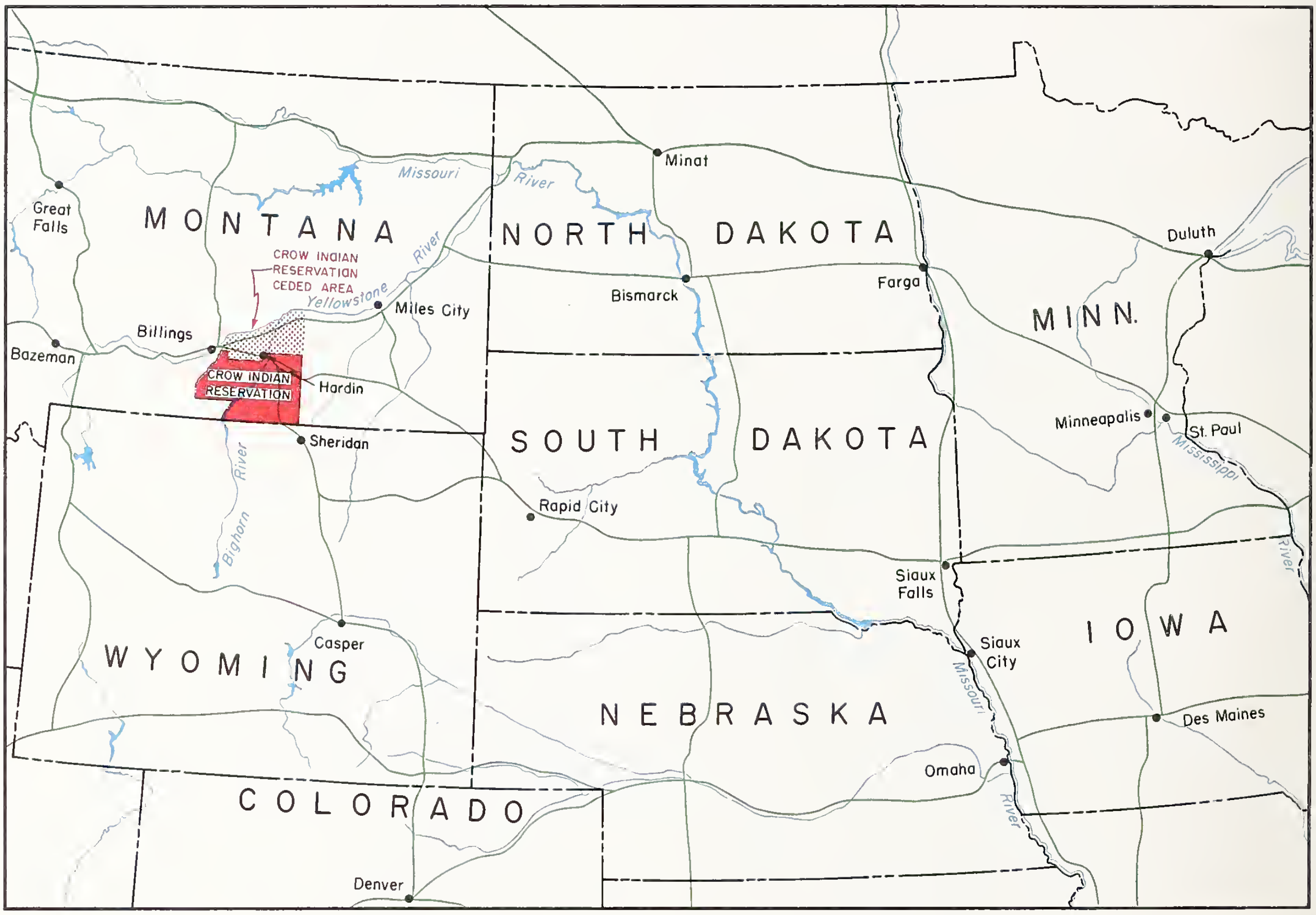
CHAPTER I

PROJECT DESCRIPTION

MAP I

LOCATION OF THE CROW INDIAN RESERVATION IN SOUTHEASTERN MONTANA



CHAPTER I

PROJECT DESCRIPTION

This impact statement projects, in broad terms, the probable environmental effects of developing the coal resources of the Crow Indian Tribe. The statement is "programmatic" in that it studies the probable effects of large scale coal development throughout the Crow Reservation and its Ceded Area rather than a specific mining or coal utilization plan.

The purpose of this statement is to provide analyses of probable impacts of coal development on the Crow people and their resources. It does not recommend policy, nor is it a proposal for development. The study does not advocate any manner, level, or type of coal development, nor does it represent the views of any particular individual or group regarding such development.

Two legally separate, but geographically adjacent, areas have been investigated. One is the two-township-wide strip lying along the eastern boundary of the Crow Indian Reservation. The other is the Crow Ceded Area, immediately north of the reservation line, and important to the Crow people since rights to the coal underlying part of the area are owned by the tribe, though the surface is mostly in fee status and nearly all owned by non-Indians.

Only one plan for the extraction and use of the coal has been finalized by the energy companies holding permits and leases with the Crow

Tribe, and that plan has already been the subject of an environmental impact statement.(1) Thus, the analysis contained in this statement for the remaining development must necessarily be based on a set of assumptions and is therefore highly tentative. Such analysis is based on two assumed levels of coal production and utilization, a low level and a high or maximum level. At the low level, it is assumed that 20,000,000 tons will be mined annually, while at the high level, yearly production would be 90,000,000 tons.

From the impacts which are anticipated at these two levels, the reader may surmise the probable impact of intermediate levels of development. Such information can provide the decision maker with an overview of the cumulative effects of mining and processing the Crow coal on both the natural environment and the social fabric of the tribe. Assuming that specific mining plans and proposals for coal extraction are developed, specific environmental assessments of these projects and their probable consequences will be completed in compliance with the National Environmental Policy Act of 1969.

In fulfilling its trust responsibilities to the tribe, the Bureau of Indian Affairs has a dual role to play in any agreement between the Crow people and the mining companies. First, the Bureau is required to provide technical and legal assistance to the tribe in all aspects of coal development, particularly with respect to the environmental effects which strip mining will have on the area. Second, the Bureau has the responsibility, under the National Environmental Policy Act of 1969, for preparing an environmental statement assuring that national environmental goals are being met and laws are being observed.

The United States Geological Survey has a statutory responsibility to the Crow Tribe in advising them on lease terms, inspecting mine operation and examining such operation with advice to the tribe on degree of compliance.

The State of Montana is expected to demand compliance with State laws and regulations in that the State has jurisdiction over the surface rights in the Ceded Area.

LOCATION OF THE CROW RESOURCES

The Crow Reservation, an area of approximately 2,226,000 acres, lies in south central Montana, and extends to the Wyoming border. The Big Horn River bisects the reservation, meeting its main tributary near the Big Horn County seat of Hardin, some 50 miles east of Billings.

Adjoining the reservation on the north is the 1,100,000-acre Crow Ceded Area, where the Crow Tribe holds extensive mineral rights. This area is bounded on the north by the Yellowstone River, and lies due east of Billings. It includes the Treasure County seat of Hysham.

EXISTING COAL LEASES AND PROSPECTING PERMITS

Essentially all of the coal reserves on the Crow Reservation have been placed under exploration permits or leased in three sales in 1968, 1969, and 1970. The one exception is the area lying between the permits held by Peabody and Gulf along the eastern end of the reservation. This area, on which no bids were received, is being retained by the Crow Tribe and will be designated in this statement the "Crow Reserve Area." A summary of the leases and permits is found in Table 1.

CROW COAL LEASES AND PERMITS

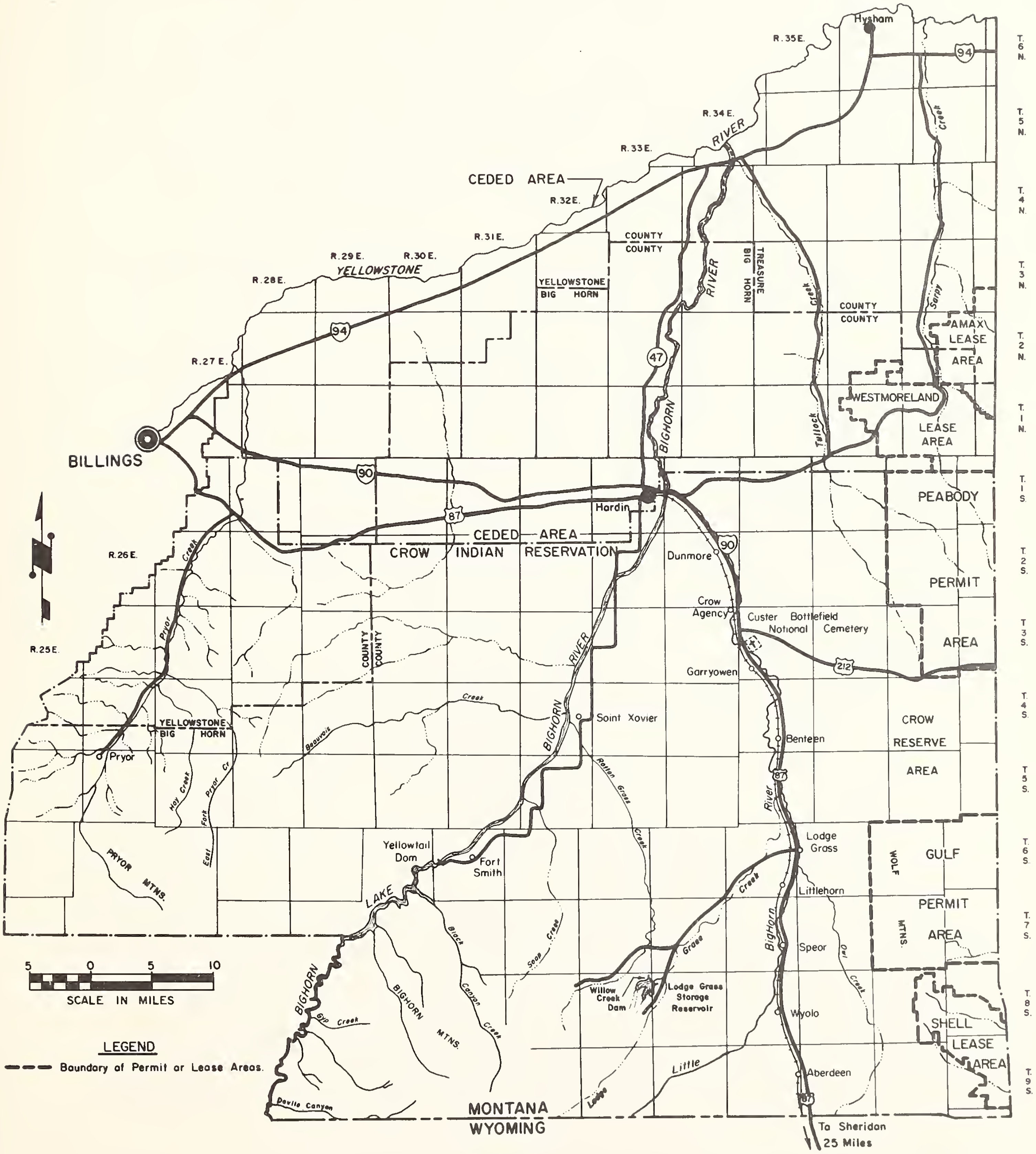
Table 1

Tracts	Acreage	Average Bonus/Acre	Successful Bidder	Status June 30, 1974
Coal Sale #1	Acres	Dollars	(Assignee in Parentheses)	(Lease Acreage In Parentheses)
Tract 1	86,122	1.02	Peabody	Permit
4	82,725	12.97	Shell	Lease (30,248)
Coal Sale #2				
Tract 7	20,704	0.10	Gulf	Permit
8	14,440	3.59	Gulf	Permit
9	21,095	2.46	Gulf	Permit
10	17,055	9.03	Gulf	Permit
Coal Sale #3				
Tract 1	3,396	1.03	Norsworthy & Reger (WR)*	Dropped
2	16,130	6.35	E.B. Leisenring, Jr. (WR)*	Lease (ALL)
3	14,746	24.21	do	Lease (ALL)
5	16,167	15.53	Ayrshire Coal Co. (AMAX)	Lease (14,237)

* Westmoreland Resources

MAP 2

CROW RESERVATION AND CEDED AREA SHOWING COAL PERMIT AREAS AND OTHER FEATURES



Crow Coal Sale Number 1

In April of 1968, four tracts were offered for prospecting permits. Peabody and Shell bid on Tracts 1 and 4 respectively. They were successful and received exclusive exploratory permits for a two year period, with the option of leasing any or all of their respective tracts during the life of the permit.

Subsequent to the granting of the permit in July 1968, Peabody obtained a two year extension (September 28, 1970). Although it has expressed a desire to do so, Peabody has not gone to lease on Tract 1.

The Shell Oil Company permit was approved in June 1968 and extended for two years on June 6, 1970. One June 8, 1972, Shell went to lease on 30,248 acres of Tract 4, the agreement covering a 10 year period or as long as coal is produced in paying quantities. A surface lease was not included.

Crow Sale Number 2

In July of 1969, ten tracts were offered for permit. These ten tracts encompassed basically the same area as Tracts 2 and 3 of Coal Sale Number 1 for which no bids were received. Gulf Minerals Resources Company, which was granted exclusive exploration permits for two years with option to renew on Tracts 7 through 10, has since exercised its option and has expressed a desire to go to lease on substantial portions of its permit area. However, the company's right to go to lease is being held in abeyance until the completion of the required Environmental Impact Statement. No bids were received on Tracts 1 through 6.

Crow Sale Number 3 (Ceded Area)

Coal in the Crow Ceded Area was offered for prospecting permits in September of 1970. Norsworthy and Reger submitted the high bid for Tract 1 and assigned the permit to Westmoreland Resources; however, Westmoreland did not renew the permit or go to lease. Tracts 2 and 3 were permitted to E.B. Leisenring, Jr. He also assigned the permits to Westmoreland, which later went on to lease the tracts. Ayrshire Coal Company was the high bidder on Tract 5, and has since leased most of the tract.

On December 6, 1974 the Secretary of Interior approved certain amendments to the leases on Tracts 2 and 3. The amendments provided for protection against Westmoreland Resource's holding coal on these tracts for speculative purposes by establishing projected levels of production; for increased royalties; and for tribal approval of the development of any mine mouth generating or gasification facility on or near the reservation. In addition the tribe obtained an option to acquire lands on these tracts subsequent to mining and reclamation.

Future Leasing

With the exception of the Crow Reserve Area, all Crow land with known coal resources have either been leased, or interest has been shown by permit holders in leasing all or part of the acreage under permit. Any future leasing activity is expected to be limited to those areas already under permit, assuming that negotiations between the companies and the Crow Tribe are successful.

The Quantity of Coal

Very little published information is available which describes the coal resources on the Crow Reservation and the Crow Ceded Area. Most of that information is summarized in a 1966 preliminary report by the Bureau of Mines entitled "Mineral Resources and their Potential on Indian Lands, Crow Reservation, Big Horn and Yellowstone Counties, Montana." (2)

The Crow coal resources are located in a two-township-wide strip running north and south along the eastern edge of the reservation and extending into the southeastern corner of the Crow Ceded Area, as shown in Map 2 (page 5) which outlines permit areas.

The major part of the coal resources in the southern sector are on the east slope of the Wolf Mountains. In the central and northern portions of the reservation, the coal seams are generally found near the summits of the mountainous terrain and contain less coal than the areas to the south. In the Crow Ceded Area, where the deposits are limited essentially to the southeast portion, the coal deposits are again thick.

There are 15 to 20 major coal seams present in the Crow coal resource area, and at least one seam is reported to be more than 50 feet thick. In some areas multiple seam mining will be employed.

Westmoreland Resources Company, American Metals Climax Incorporated, Gulf Minerals Resource Company, Peabody Coal Company, and Shell Oil Company have recently conducted extensive prospecting operations on their respective permit lands in the Ceded Area as well as on the

Crow Reservation. From company reports and information on the Tribal Reserve Area, it appears that approximately 4 to 4½ billion tons of strippable coal has been located, of which an estimated 650 million tons is in the Ceded Area. Indications are that there is an additional 6 to 12 billion tons of coal which has too much overburden to mine economically, considering present stripping methods and coal prices.

The Quality of Coal

A summary of the physical and chemical properties typical of coal from the Crow resource area is shown in Table 2.

Table 2 Partial Physical and Chemical Analysis of Crow Coal

Proximate Analysis

Reservation Coal

Component	Range in Percent by Weight		
Moisture	21.4	-	24.6
Volatile matter	33.3	-	28.4
Fixed carbon	40.3	-	35.9
Ash	5.0	-	11.1
	100.0		100.0
Sulfur	0.4		1.0
BTU/pound	9,000		8,300

Ceded Area Coal

Component	Percent by Weight
Moisture	25
Volatile matter	29
Fixed carbon	37
Ash	9
	100
Sulfur	0.7
BTU/pound	8,450

THE PROJECTED LEVELS OF DEVELOPMENT

Except for the Westmoreland operation in the Crow Ceded Area, and a recently submitted Shell plan for an operation in the extreme southeastern corner of the reservation, no specific mining plans for coal extraction and use have been presented to the tribe or responsible government agencies. Therefore, in preparing the programmatic environmental statement, it is necessary to make certain general and specific assumptions so that the study team will have a base from which to conduct its analysis.

The first general assumption is that the appropriate governing bodies, including the Crow Tribe, as well as the counties and municipalities affected, will carry out an effective land use planning and control program. A second general assumption is that all appropriate Federal, State and local environmental standards, as well as those stipulated in the lease, be effectively enforced.

For this statement, the primary set of specific assumptions concerns two levels of coal development, the lower being limited to three mining operations for coal export, and the higher to six mines and three conversion plants. Associated assumptions include projections of employment, population growth, water use, land reclamation practices, waste disposal systems, community structure, and transportation. The assumptions used are all based on discussions, both formal and informal, between the tribe and the companies involved.

The low level, representing a projected minimum level of development, assumes that there will be three strip mines, two to be opened on the Crow Reservation and one presently operating in the Ceded Area. Each of the on-reservation mines is projected to extract 5,000,000 tons annually, while the mine in the Ceded Area is projected to produce 10,000,000 tons--a total annual production of 20,000,000 tons. At this projected low level of development, all the coal mined would be shipped out of the immediate area of the reservation.

It should be emphasized that the assumed locations and production levels of the mines have been established for analytical purposes only. These must not be taken as predictions of specific mining sites or production levels. Recent amendments to the leases have increased projected annual production to approximately 19,000,000 tons annually by about 1990 from the Westmoreland operations in the Ceded Area. This indicates that the low level assumption could be met on the Ceded Area alone.

The high level of development assumes that a total of 90,000,000 tons of coal will be mined annually. This includes continuation of the two 5,000,000-ton mines on the Crow Reservation and additional production of 60,000,000 tons from other mines used primarily for supplying mine-mouth gasification and liquefaction plants. Development at this high level on the Crow Ceded Area assumes the expansion of the 10,000,000-ton mine to 15,000,000 tons annually and the opening of another 5,000,000-ton strip mine. Of the Ceded Area coal, 10,000,000 tons will be used by a gasification plant and an associated power plant.

It is on the basis of these two levels of coal resource utilization that this programmatic statement has been prepared. It is again emphasized that project descriptions found later in this chapter under the two levels of development, are based on assumptions considered reasonable for minimum and maximum levels of development. It is, of course, assumed that intermediate production levels will occur after the low level work has begun and before the high level is reached. Because of the infinite number of levels possible in these intermediate stages, all projections are based on the two extreme levels of development. Several optional intermediate levels will be discussed in the alternatives chapter.

No specific time frame has been used for the projected levels of development. It is anticipated that the low level of development will be met by approximately 1980. The high level, if it is attained, will probably require an additional 10 to 20 years.

LOW LEVEL DEVELOPMENT ASSUMPTIONS

Of the three typical strip mines assumed as the basis for the first development level, the first mine has recently begun operations in the southeastern part of the Ceded Area. The mine is served by the Burlington-Northern Sarpy Creek spur line from the main line rail head at Sanders, Montana. The second mine is projected to be located in the northeast corner of the Crow Reservation and will be designated the "Northern Reservation Mine." The third mine is assumed to be the proposed Shell operation in the extreme southeastern portion of the Crow Reservation. For convenience, it will be called the "Southern Reservation Mine." As stated before, it is assumed that coal from these mines will be shipped by rail out of the state. Table 3 summarizes some basic features of the low level of development.

TABLE 3 LOW LEVEL DEVELOPMENT FACTUAL SUMMARY

	SOUTHEAST CEDED AREA MINE	NORTHERN RESERVATION MINE	SOUTHERN RESERVATION MINE	TOTALS
AREA DISTURBED 1ST YEAR (ACRES)	575	695	360	1,630
AREA DISTURBED EACH YEAR THEREAFTER (ACRES)	125	330	80	535
AREA RECLAIMED EACH YEAR (ACRES)	125	330	80	535
COAL MINED ANNUALLY (TONS)	10,000,000	5,000,000	5,000,000	20,000,000
MANPOWER REQUIRED (NORMAL STAFF)	225	112	112	449
WATER REQUIRED ANNUALLY (ACRE FEET)	280	140	140	560

Southeast Ceded Area Mine

This mining plan contemplates the stripping of up to 125 acres per year and the annual mining of 10,000,000 tons of sub-bituminous coal throughout the life of the project. An additional 150 acres will be disturbed the first year by spoil bank placement, while an adjacent 200 acres will be altered by the construction of plant facility roads, sediment ponds, rail loading sites, etc. One hundred acres elsewhere will be disturbed for rail spurs and highway supplying the mines.

Northern Reservation Mine

This mining plan contemplates the stripping of up to 330 acres per year and the annual mining of 5,000,000 tons of sub-bituminous coal throughout the life of the project. An additional 115 acres will be disturbed the first year by spoil bank placement, while an adjacent 150 acres will be disturbed by the plant facilities, storage area, roadways, rail loading site, etc. Some type of dam and holding basin will be necessary downstream on the principal drainage to control sediment. Another 100 acres may be disturbed by a rail spur and/or highway, which would provide access to the mine.

Southern Reservation Mine

Stripping up to 80 acres per year for some 5,000,000 tons of coal per year, this mine will require fewer acres to produce the same tonage as the Northern Mine because of its thicker coal seams. The mine and its supporting facilities will be similar to those described in the previous sections, and the following discussion will be applicable to a greater or lesser extent to all. The total acreage disturbed will differ and is tabulated in Table 3.

Mine Staffs

During operation, a staff of at least 112 people will be needed at each of the mines producing 5,000,000 tons per year (the Northern and Southern Reservation Mines). At the Southeastern Ceded Area Mine, approximately 225 personnel will be required to produce the 10,000,000 tons per year anticipated mine capacity. These will include management personnel, foremen, equipment operators, and laborers. This allows for three shifts for a portion of the operating personnel. More detailed information on the influx of workers and payrolls in the area is found in Chapter III.

Coal Seams

Several coal seams will be mined at the Southeast Ceded Area Mine, mainly the Rosebud-McKay Seam (approximately 30 feet in thickness) and the Robinson Seam (approximately 20 feet in thickness). The average overburden to stripping ratio for the total recoverable reserves in this mine is estimated to be about 3.9 cubic yards of overburden to one ton of coal. The average depth of overburden above the Upper Rosebud-McKay Seam is approximately 90 feet. An additional 60 feet of interburden overlies the Robinson Coal Seam.

Coal seams in the northern part of the reservation average only about 10 feet in thickness and are generally found in the higher terrain. It is assumed that only one seam will be mined. There are local areas of thicker coal, but, in general, the thick coal seams are found farther south.

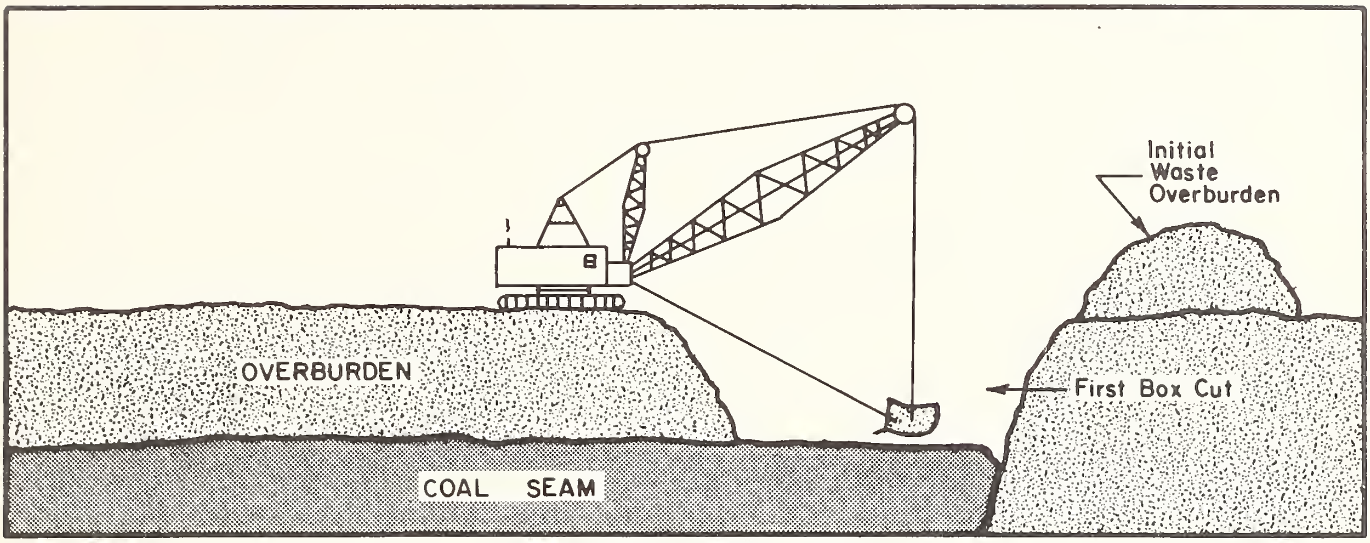
There are several mineable coal seams in the central and southern sectors of the coal reserve area of the reservation. These seams vary from three to 50 feet in thickness, and the interval between the seams varies from five to 200 feet. A typical 250-foot exploration drill hole will intersect three to five mineable coal seams. From the limited information available, it is assumed that on the average one or two seams totaling 40 feet of coal will be mined at these sites.

Mining Plans - In this report it is assumed that each of the mines will be worked by what is known as the area stripping technique. This method entails removal of the material overlying the coal seams along narrow parallel strips which usually extend longitudinally for the length of the property. Other possible methods of coal mining are described in Chapter VIII, "Alternatives to the Proposed Action." But for relatively shallow coal seams with the depth of overburden found in the vicinity of the Crow Indian Reservation, area stripping appears to be the most economical method available with today's technology. This method, as described in the study, is employed in similar mining areas in Montana and Wyoming.

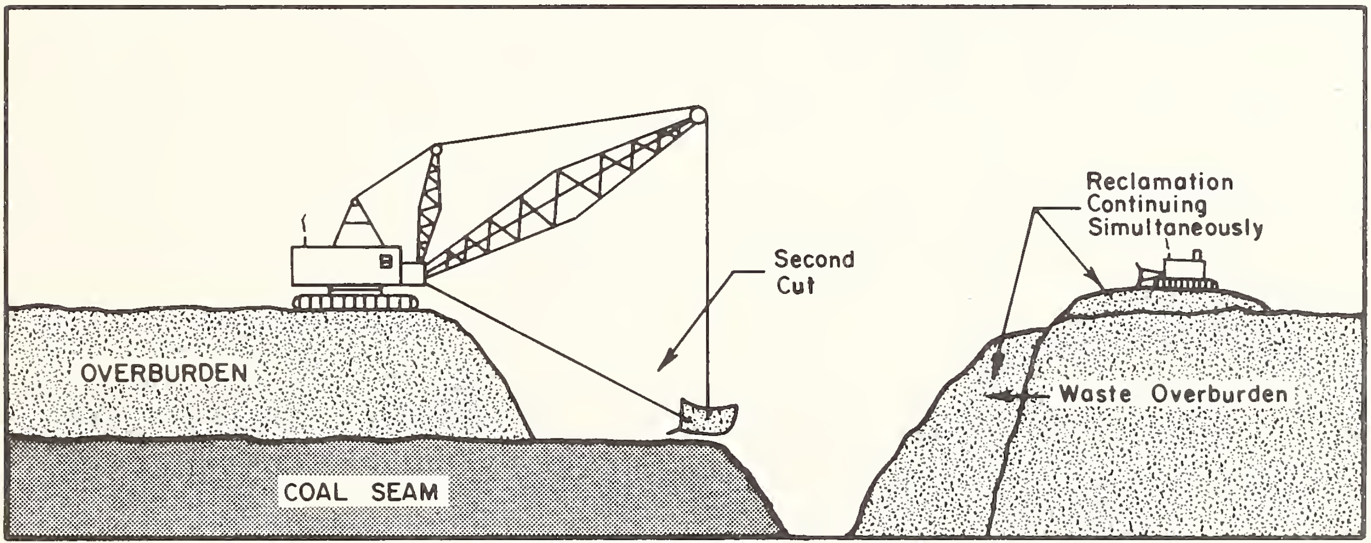
Because of the nature of the overburden (shales and sandstones), large draglines will probably be used. Material from the first cut, or box cut, will be placed on land outside the area to be mined, and the underlying coal blasted and loaded into hugh off-highway trucks by large front-end loaders for transport to the plant facilities. After the box cut is completed, a second cut will be dug alongside it, and the excavated material discarded into the box cut. Each mine will be excavated and the coal removed, with successive cuts continuing across the coal seam, until the opposite side of the seam or the edge of the property is reached.

FIGURE 1

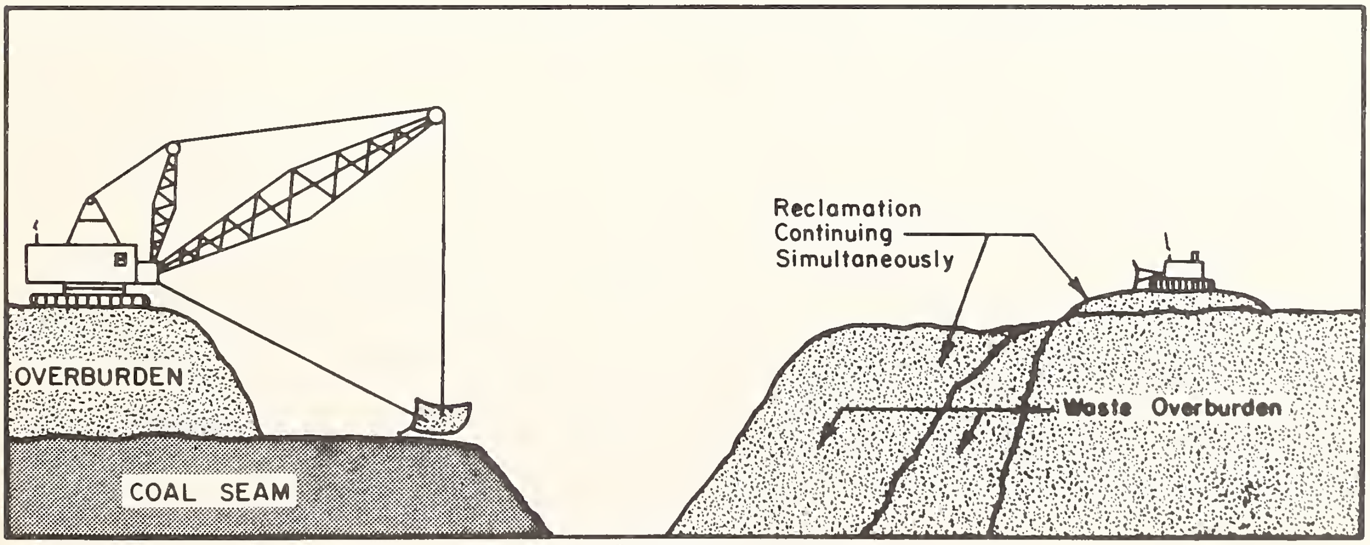
CROSS-SECTION OF AREA STRIP MINING TECHNIQUE



(A) THE FIRST CUT



(B) THE SECOND CUT



(C) SUCCEEDING CUTS

Reclamation of the previously mined areas will be carried on simultaneously with the mining of coal as additional cuts are made. Assuming that reclamation requirements will be stipulated in the leases to equal or exceed those required by the State of Montana, the outside of the spoil bank will be shaped to a maximum gradient of 11°, except in certain areas of unusual original topography where it will be shaped to a maximum gradient of 19°. All interior spoil banks will have a maximum gradient of 11°, and the final high wall will be reduced to a maximum of 20° at the conclusion of mining.

Usable topsoil overlying the areas of spoil placement and the areas to be mined in the box cut will be removed and stockpiled by scrapers or bulldozers. The topsoil and other suitable overburden material from the next cut will be moved to the recontoured spoils prior to the seeding of the area.

These areas will be revegetated with grasses and other vegetation found by testing to be compatible with the climate and soil conditions at the mine sites.

Plant Facilities - The coal handling facilities for each mine will consist of a truck dump and crusher area, a coal storage lot, and freight car loading hoppers. Also included will be various conveyor structures, a rail yard, shop, service, and office buildings.

Roads - Access roads will be needed from the nearest gravel or paved secondary roads. An interior system of haul roads will extend from the plant facilities into each strip mine. These must be on easy grades and may entail deep cuts, depending upon the terrain.

Utilities - Since the dragline will be electrically powered, an overhead high voltage power line must be run to the nearest power transmission line. Within the mine areas, high voltage insulated cables will extend along the ground to the equipment. Interior distribution must conform to the Federal Coal Mine Health and Safety Act of 1969.

Deep wells will be required to provide water for fire and dust control and also for the small amount of water required for the crews working at the mines. An average of approximately 125,000 gallons per day will be needed for these uses on the reservation mines. Up to 250,000 gallons per day will be required for the Ceded Area mine. That portion required for domestic needs may require treatment to render it potable.

Sewage collection systems will be required to serve the operating crews at each of the mines. They will discharge into small sewage treatment plants which must provide secondary treatment in accordance with Environmental Protection Agency requirements. The applicable legislation is listed in Chapter IV.

Drainage System and Sediment Control - Mine drainage systems must be designated to handle storm runoff and ground water which accumulates in the mine cuts. Pumping may, under certain conditions, be necessary to prevent the ground water seepage from remaining in contact with exposed coal or waste and thus dissolving undesirable chemicals.

Mine drainage will not be allowed to flow directly into major watercourses in the drainage basins, since it could carry chemical contamination and most certainly would carry sediment from the unconsolidated fill, particularly after storms. This water may be retained in holding basins for natural clarification and possible chemical treatment (if, for instance, it has a low pH from acid formation). At the mines where the terrain does not lend itself to a dam and holding reservoir, the course of the receiving stream could be diverted through a series of settling ponds. These ponds would be so sized and shaped that their detention time would be adequate to allow natural sedimentation. Quality in the receiving streams cannot be degraded below stream standards. Federal legislation, listed in Chapter IV, provides for the enforcement of these requirements.

Railroad Spur Lines - Burlington Northern, Inc., recently constructed a new railroad spur line which is serving the Southeastern Ceded Area Coal Mine. It originates from Burlington Northern's main line at a point approximately two miles west of Sanders, Montana, and in general, follows along Sarpy Creek for a distance of 36 miles to the coal mine loading site.

It is assumed that a rail spur meeting these same specifications will connect the Northern Reservation Coal Mine loading yard to the Sarpy Creek spur in the Ceded Area, 10 to 20 miles north. It will follow the west fork of Sarpy Creek farther south and possibly cross into the Tullock Creek drainage basin in its upper reaches. As with the present line, this spur will carry unit trains from the mine to the main line of the Burlington Northern near Sanders, Montana, and thence to market.

The railroad right-of-way will be fenced with hog-tight fencing and a number of reinforced concrete cattle passes will be placed at various locations, as required by owners of abutting property through whose lands the spur line will extend. Culverts, bridges, and road crossings will be designed to meet the specifications of the Burlington Northern and the requirements of the Bureau of Indian Affairs and State of Montana.

It is further assumed that a rail spur line will connect the Southern Reservation Coal Mine loading yard with an extension of the existing Burlington Northern spur line which now services the Decker Coal Company mine near Decker, Montana. A logical route is along the Youngs Creek valley to its termination point or north to the Crow coal reserve area. This spur line will carry unit coal trains from the mine to the Burlington Northern main line near Sheridan, Wyoming, and from there the coal will be shipped to midwestern or other marketing areas.

Market Area - The coal from all of the mines will be shipped by rail either directly to existing out of state power generating plants or to a barge terminal on the Mississippi River and floated to the plant customers. A portion will replace midwestern and eastern coal, which with its high sulfur content, causes air pollution in many areas.

HIGH LEVEL DEVELOPMENT ASSUMPTION

For the analyses on the high level of development, it is assumed that the three mines previously discussed under the low level assumption will continue. In addition, two extremely large strip mines will be opened on the Crow Reservation proper, in areas having extensive coal reserves. A gasification and power plant combination will be located near the one mine, while a liquefaction and associated power plant will be located near the other.

The first mine and conversion plant will be designated Complex A, and the second, Complex B. A total of 70,000,000 tons of coal will be mined annually under this assumed level of development on the reservation.

On the Ceded Area, high-level development would consist of an annual production increase to 15,000,000 tons at the mine projected for the low level of development, and the addition of a 5,000,000-ton mine at another location.[1/] Installation and operation of a gasification plant and associated power plant, designated Complex C, would be the extent of additional industrial development on the Ceded Area.

A combined total of 20,000,000 tons of coal will be mined annually in the Ceded Area under this assumed level of development. The combined production from high-level development of all Crow coal reserves is projected to total 90,000,000 tons annually, including the estimates set forth for the low level of development. A capsule of the main features of the high level of development is presented in Table 4.

Complex A

Complex A is assumed to be in the northern or central portion of the Crow Reservation where 30 million tons of coal will be mined each year. The mine itself will be similar to those discussed previously, but on a much larger and more complex scale; so large, in fact, that it might

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1/ The recent lease amendments referred to on page 11 would indicate that, at the high level, Ceded Area coal production is expected to be in the range of 25 to 30 million tons annually.

TABLE 4

HIGH LEVEL DEVELOPMENT FACTUAL SUMMARY

	NORTHERN RESERVATION MINE	SOUTHERN RESERVATION MINE	COMPLEX A	COMPLEX B	COMPLEX C CEDED* AREA MINE	CEDED AREA MINE NO.2	TOTALS
AREA DISTURBED 1ST YEAR (ACRES)	695	360	2,400	2,400	1,220	575	7,650
AREA DISTURBED EACH YEAR (ACRES)	330	80	500	500	200	125	1,735
AREA RECLAIMED EACH YEAR (ACRES) **	330	80	500	500	200	125	1,735
COAL MINED ANNUALLY (TONS)	5,000,000	5,000,000	30,000,000	30,000,000	15,000,000	5,000,000	90,000,000
PIPELINE GAS SHIPPED (SCF/DAY)	---	---	885×10^6	---	300×10^6	---	$1,185 \times 10^6$
OIL REFINED & SHIPPED (BBLS/DAY)	---	---	---	200,000	---	---	200,000
POWER **GENERATED** (KILOWATTS)	---	---	120,000	1,360,000	40,000	---	1,520,000
MANPOWER REQUIRED (NORMAL STAFF)	112	112	2,575	2,605	875	112	6,391
WATER REQUIRED ANNUALLY (AC. FT.)	140	140	76,000	84,000	26,000	140	186,420

* This includes the original southeast Ceded Area mine expanded to an annual capacity of 15,000,000 ton, of which 10,000,000 will be utilized in gasification.

** After third year of operation.

function as a number of smaller connected mines. There will be several major differences between it and the smaller mines discussed under the low level. Except for these, the mine will not be described again in detail (although its greater impacts will receive attention in Chapter III).

Coal Seam - There are several mineable coal seams in the southern and central parts of the reservation. These seams vary from three to 50 feet in thickness, and the interval between the seams varies from five to 200 feet. It is assumed that one or more seams will be mined for a total of at least 40 feet of recoverable coal.

Mining Plan - The equipment will be essentially the same type, but the amount used will be dramatically greater than at the mines in the lower-level development plans. It is anticipated that as many as six huge draglines will be operating simultaneously in one mining complex, with many more trucks and haul roads required than for the low-level mines.

The land disturbed annually will approach 500 acres, and in the first year as much as 800 additional acres will be needed for spoil bank placement, plant facilities, roadways, headquarters, storage and other requirements. Small dams and settling reservoirs will be needed on the watercourses leading from the mine site to minimize downstream pollution from sediment and chemicals.

Mine Plant Facilities - It is assumed that the three additional mine plants will be similar to those for the low level but will be larger or multiple units utilizing some common facilities. Each will probably have truck dumps, crushers, storage areas, and service buildings. They will probably not have a rail yard or office building. Instead of a rail line, conveyors may carry the coal to the gasification plant. An office building will be needed for Complex A, located probably near the gasification plant, and there will probably be a group of office and service buildings.

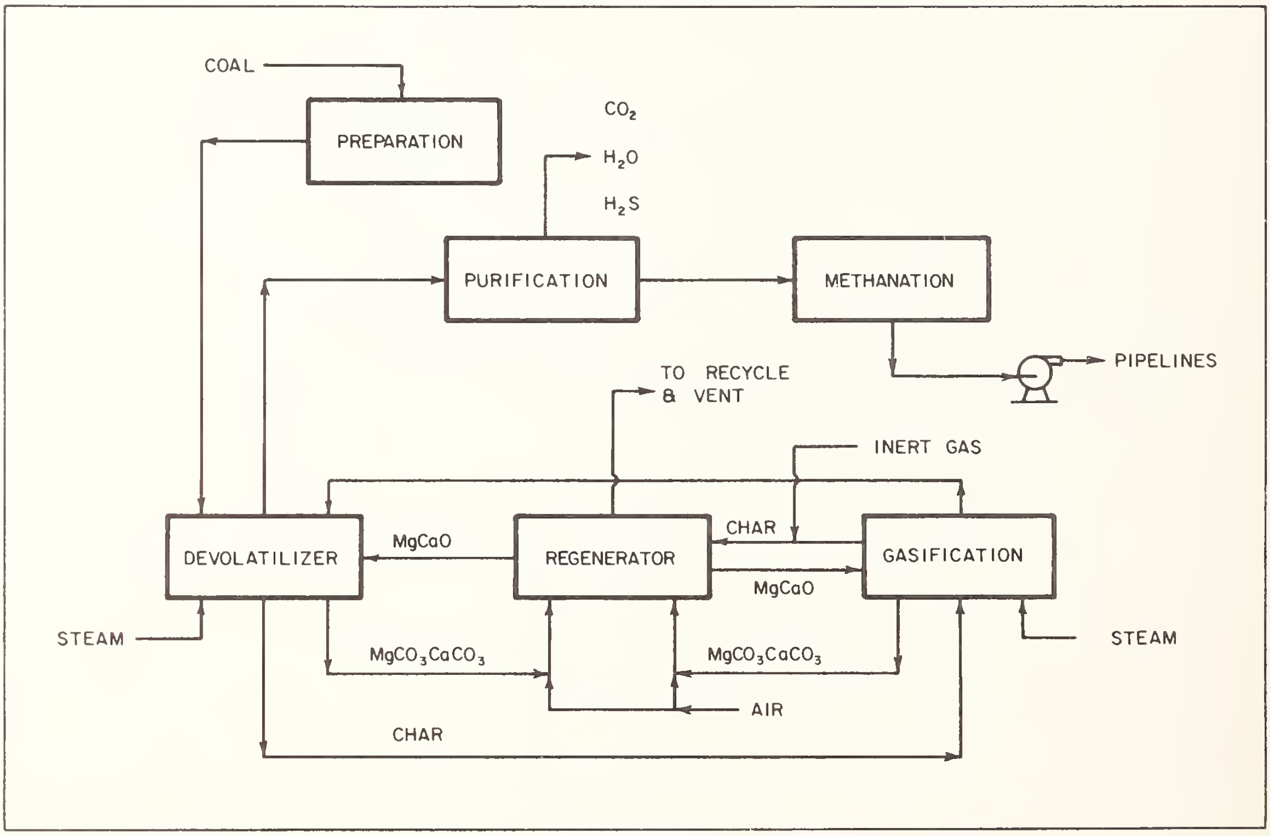
Roads and Utilities - As with the low-level operation, roads and utilities will be needed, the difference being one of degree and type. Several roads will be needed, including a major paved road from Lodge Grass, Montana. A large quantity of water will be required for the mine's needs, and it will be supplied from deep wells. Several effluent treatment plants may be needed, but in other respects, the facilities will be similar to those of the low-level development.

Gasification Plant - Under the assumptions established, the coal extracted from the mine in Complex A will be used to supply a gasification plant. Gasification processes have reached a high state of development and are capable of producing methane gas suitable for burning in power generating plants and, with further refining, for high quality pipeline gas.

The Office of Coal Research is investigating several processes that will produce a high quality methane gas more efficiently and at less cost than the Lurgi process now used in Europe. All show promise, and it is likely that one or several of these processes will be used commercially in the 1980's and thereafter.

For purposes of analysis, it will be assumed that the gasification plant will use the CO_2 Acceptor Process developed by Consolidated Coal Company. It has been described as a promising approach for the future.(3) In this statement, the impacts on the environment, such as air pollution and water use, refer to this process, which is illustrated in Figure 2.

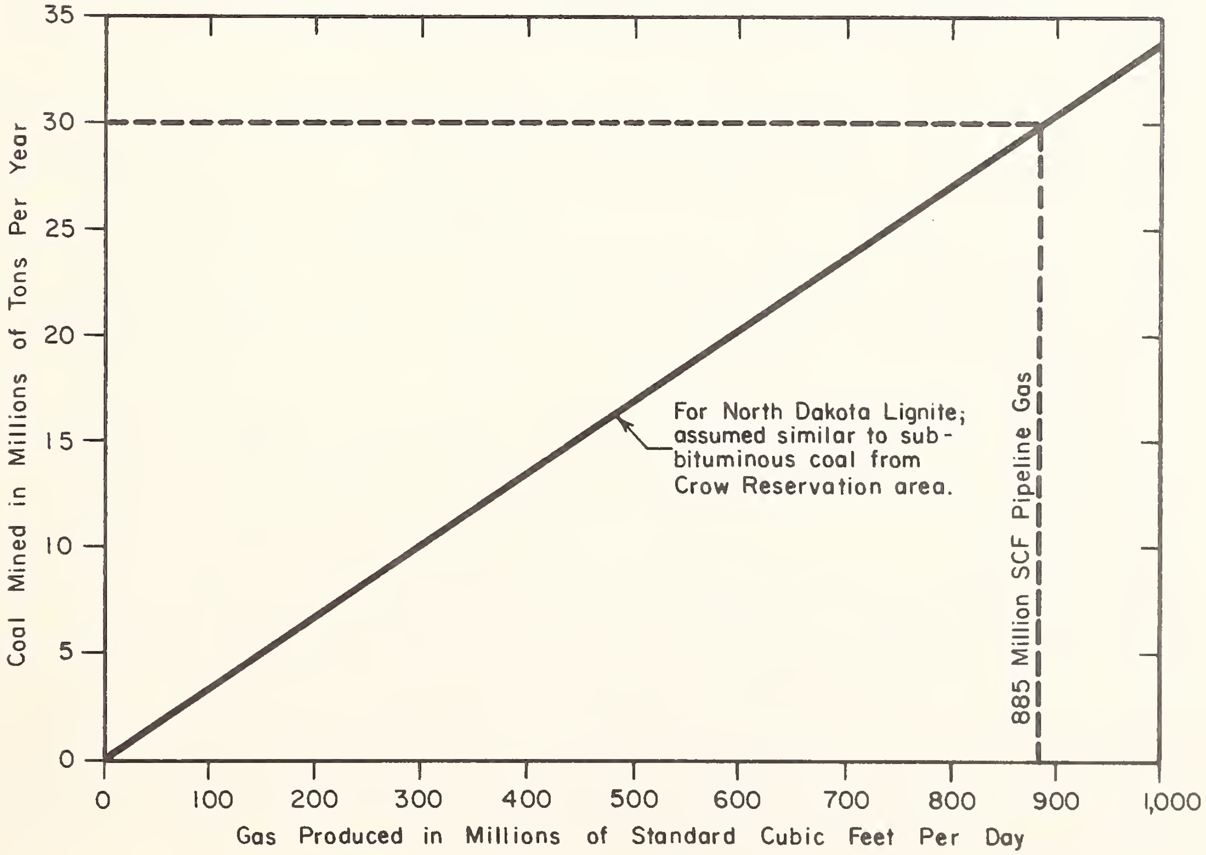
FIGURE 2
SCHEMATIC DIAGRAM
COAL GASIFICATION PROCESS



In the CO_2 Acceptor method, crushed coal is fed to a devolatilizer where it reacts with hydrogen-rich gas from a gasifier. The residual char is transferred to the gasifier where the carbon reacts with steam. Calcined dolomite derived from limestone acts as a heat carrier and moves through the devolatilizer and gasifier. The mixture of dolomite and residual char from the gasifier is transferred by a conveyor system to the regenerator where the char is burned to heat and recalcinate the dolomite. The gaseous product of the devolatilizer is purified and methanated to form pipeline gas, and excess steam is produced that can be used for power generation.

Gasification Plant Capacity - It is assumed that the plant must be designed to produce pipeline gas whose minimum quality is 900 BTU/SCF. Figure 3 shows the amount of pipeline gas produced from a given quantity of coal consumed.

FIGURE 3
APPROXIMATE RELATIONSHIP OF TONS OF COAL MINED TO AMOUNT OF PIPELINE GAS PRODUCED



From this curve, it is evident that a coal production of 30,000,000 tons per year could supply an 885,000,000-SCF-per-day gasification plant. These figures are based on studies using North Dakota lignite mentioned in reference (4). The sub-bituminous Crow coal has a 25 percent higher heat content and therefore would probably produce significantly more gas per unit of coal, although no tests have been made for Montana sub-bituminous coals.

Gasification Plant Resource Needs - Water: CO_2 acceptor plant development is in the pilot plant stage and, therefore, all requirements listed here are extrapolations of bench scale studies. The final requirements may vary if problems of large-scale production are solved.

Large quantities of water are needed both as a supplier of hydrogen and for cooling water. The studies indicate that processing one ton of ray lignite consumes about 3.5 tons of water. Three and one-half tons of water per ton of coal equals about 840 gallons per ton. Thus for 30,000,000 tons of coal mined and used per year, a water supply of 48,000 gpm is needed. Cooling and blowdown water is 76,000 ac. ft. The figure could be reduced if dry cooling or other forms of recirculation were used.

The only available source of this quantity of water is the Yellowtail Reservoir or the Big Horn River below the dam. To tap this source, a water intake and pumping structure connected to a 40- to 50-mile pipeline would be needed. Any group undertaking such a major water withdrawal program would have to obtain property rights to this water. Chapter II includes discussions of applicable water rights, Big Horn River water allocations, and industrial water marketing.

Limestone and Dolomite

Huge deposits of limestone and dolomite are present on and near the reservation. Limestone production at a yearly level as high as 85,000 tons has occurred at a mine near Warren, Montana, about 10 miles west of the reservation.

These deposits are found in the Madison Formation outcrops, which extend from Warren across the southern edge of the reservation to the Little Bighorn River. There are many potential sites for limestone mines on the reservation. Large reserves of dolomite have been found in association with the limestone; therefore, local acquisition should be feasible.

Some 1,750,000 tons of rock would be used per year, requiring a quarry, blasting and excavating equipment, and a form of transportation to the plant. It is assumed that a rail spur, which would run roughly parallel to the water pipeline for much of its length, would be the most practical means of transport.

Power Generating Plant - The gasification process generates excess steam. More than 300,000 pounds per hour of high pressure 1,000° F steam and 3,000,000 pounds per hour of low pressure 350° F steam would be produced that would not be needed for the process. This steam could be used to generate power, for it would produce about 120,000 kilowatts from a steam turbine plant. The plant could thus produce all the power consumed by the various processes and mining operations at the site and have some left over to sell to a power transmission company.

Plant and Mine Staff - It is anticipated that about 1,900 employees will be needed to staff the gasification plant and power generating plant and about 675 people needed to staff the mine. These include management personnel, operators, laborers, etc., for the mine and conversion plants at the 30,000,000 ton per year production level.

Cooling Pond - Cooling water from the power turbines and from the gasification process would probably not have to be recirculated in a closed system but could be circulated to a cooling pond where it could be reused. This would decrease cooling water requirements, resulting in a corresponding reduction in the consumptive use of water.

Ash Reservoir - Two major waste products will be ash from the combustion process and discharge from the exhaust scrubbers. It is assumed both products can be sluiced to a large sealed storage reservoir with high earthen dikes large enough to contain a sludge throughout the life of the project. A portion of the fly ash can probably be recirculated to the scrubbers to remove SO_2 and neutralize the waste, since the ash should be alkaline. Even so, as much as 650,000 pounds of ash could enter the pond each hour. The water itself should receive a high degree of clarification, considering the detention time, weight of sludge, and the fact that the fly ash should have certain flocculating properties. Therefore, this water may be recirculated for ash sluicing. A reservoir 1,800 to 1,900 acres in size and up to 50 feet deep could contain the waste sludge from 50 or more years of operation. Due to the excessive size of this facility, it may be more feasible to dewater the ash and return it to the mine for burial. Thus conveyors might be required to return the ash to the mine. But prior to this, dewatering would take place in thickeners, evaporating ponds, or other devices. While the operational costs of such a system would be great, the advantages, such as soil conditioning in the reclamation process, would also be great.

Gas Transportation - A pipeline would be required to carry the methane gas to a natural gas pipeline for distribution to the market. A natural gas pipeline exists 30 miles south of the site at Sheridan, Wyoming, and another lies about 60 miles north of the site. A large compressor station would be required near the gasification plant.

Complex B

It is assumed that Complex B, near the southern boundary of the reservation, will also be a large mining-industrial complex. Here, another 30,000,000-ton-per-year strip mine is projected, as well as a coal liquefaction plant.

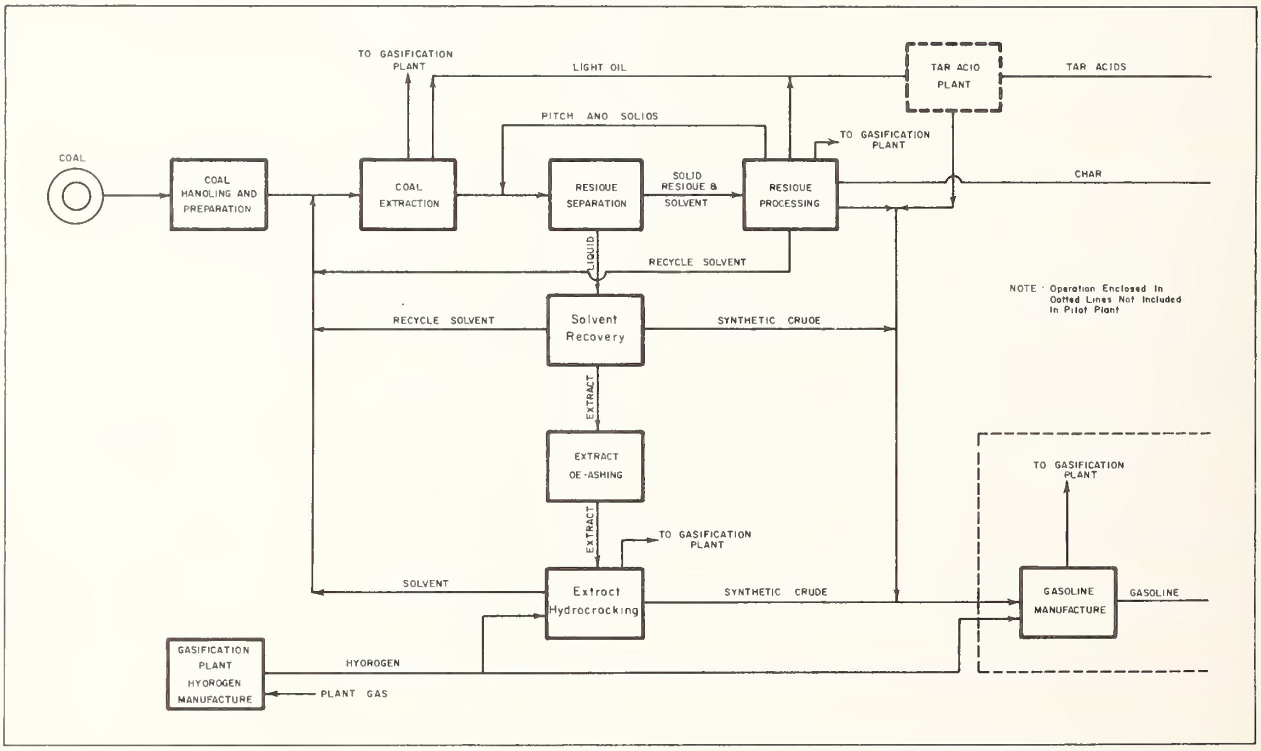
Mine - The mine will be similar to that described for Complex A, except that since the terrain is less rugged, reclamation should be easier. The paved road will extend from Wyola or Decker, rather than Lodge Grass but otherwise will be much the same. Because of the similarities, the mine itself will not be discussed further.

Coal Seam - Seams in the area of assumed Complex B mine are similar to those at Complex A.

Liquefaction Plant - The basic technology for producing synthetic oils and gasoline from coal has been available for many years, but the price has been prohibitive. When no other source of supply was available, as in Germany in World War II, production units were constructed.

However, improvements in metallurgy and system components have indicated that liquefaction could some day become competitive with petroleum products. The Office of Coal Research has taken the lead in investigating processes which show promise. In this statement one which has advanced through the pilot plant stage has been chosen for consideration. It is the CSF process developed by the Consolidated Coal Company which is shown in Figure 4.

FIGURE 4
SCHEMATIC DIAGRAM
COAL TO GASOLINE FUEL CONVERSION PROCESS



NOTE · Operation Enclosed In Dotted Lines Not Included In Pilot Plant

The CSF process begins with the crushing and mixing of coal with a solvent returned from other sections of the plant.(6) The solution is heated and the organics extracted and separated in cyclone separators and cleaning devices. The resulting liquid is distilled to recover the solvent and is fed to the hydrogenation section. There it is brought in contact with hydrogen under high pressure (4,000± psi) and high heat

($800^{\circ} \pm$ F) in the presence of a catalyst. The product is a crude oil which may be distilled for various weight oils, hydrocracked and refined into gasoline, etc. The choice of products depends upon the use of the catalyst in the hydrogenation and refining processes. The residue from the cyclones, the hydrogenation, and other processes is carbonized to remove all volatile matter which, after condensation, rejoins the solvent. The remaining char is taken from the process from steam generation and power production. A gasification plant, in part similar to that described in Complex A (up through the gasifier stage), is used to obtain the hydrogen needed. The gasifier could be the first stage of a Lurgi, HyGas, or other process. Dolomite would not be required.

Plant Capacity - In this report it is assumed the pilot plant results can be extrapolated to a full-scale operation without providing a hypothetical factor for improvements in design or efficiency, and by interchanging western coal for eastern coal. It is assumed that the gains in the one will be offset by the losses in the other.

On the basis of these assumptions the liquefaction plant will produce 74×10^6 barrels of 91-octane gasoline per year, or 200,000 barrels/day. To produce this amount of gasoline, roughly 60 percent of the coal entering into the process will be used directly in the liquefaction process and 40 percent will be used to produce hydrogen, which in turn is used for liquefaction.

By-Products and Power Production - About 30 percent of the coal input will remain after carbonization and other processes. It will be a char whose heat content will be at least 6,000 BTU/pound. Thus, 9,000,000 tons of this residue will be available for processes other than liquefaction.

It can be used either to produce hydrogen in the gasification phase or to produce power. Since it is believed that char would produce less air pollution than coal in the generation of power, it is assumed the char will be transported, while still hot, to an adjacent power plant for steam generation. If the station heat rate is assumed to be 9,000 BTU/KWH and the plant is used for base load production, a capacity of 1,360,000 Kw will result. This power would be used in the various processes and plants and sold to the power distribution system. The description of the generation plant facilities follows.

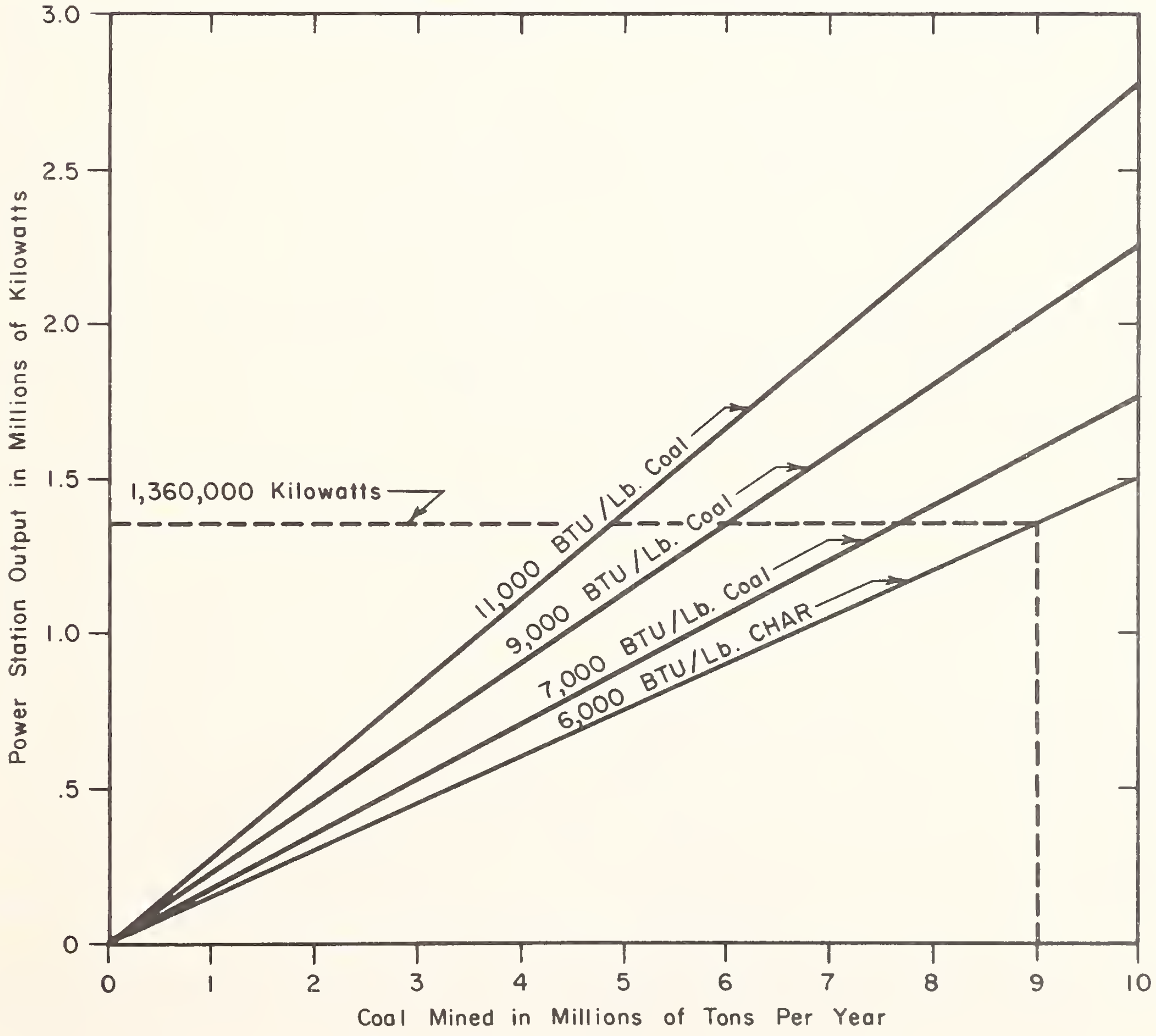
Power-Generating Plant - Since this will be a moderately large power plant, constructed with the most modern control and generating equipment, it is assumed that the plant will be used continually to generate base-load power and not used intermittently for peaking loads. A graph was devised to relate tons of coal mined to amount of power generated as shown in Figure 5. To compute the various points needed for the curves, it was assumed the heating value of the coal or char could be 6,000, 7,000, 9,000, and 11,000 BTU's per pound and that the average station heat rate will be 9,000 BTU's per KWH. The computations are in Appendix A.

From the computations and graph, it appears that for 6,000-BTU coal, the 9,000,000 tons of char per year will produce 1,360,000 kilowatts. It is assumed this power will be provided by four electric generating units, each containing a steam generator, a turbine generator, and necessary pumps, piping and auxiliary equipment. These units will be housed in the main plant building. Plants of this size use close to 10,000,000 pounds of super-heated steam (1,000°F+) per hour from a closed system.

FIGURE 5

APPROXIMATE RELATIONSHIP OF TONS OF COAL MINED TO AMOUNT OF POWER GENERATED

(FOR STATION HEAT RATE OF 9,000 BTU/KWH)



To reduce the formation of oxides of nitrogen in the stack, the furnace will presumably be of a type designed for recycling and excess oxygen control. The stack itself will be high enough to obtain a satisfactory dispersion of gases. (Further discussion is contained in Chapter III, Environmental Impacts.) To reduce the escaping particulate matter and sulfur dioxide to meet Environmental Protection Agency criteria, wet scrubbers utilizing a limestone-feeding device will be installed if necessary on each steam generator. Probably, the high pH of the fly ash will preclude the need for limestone.

Cooling Towers - Large quantities of water will be needed to cool the super-heated steam. Since the warmed water cannot be returned to its river source, because of the adverse effect on stream life, it must be cooled. Because of pumping costs associated with water supply and return for an open system, the water will probably be recirculated. Therefore, two wet-type cooling towers, each of natural or mechanical draft design and connected to a closed system, will be needed.

To prevent buildup of dissolved solids, a blowdown arrangement to a waste water basin will be required. The basin will accept scrubber blowdown, water from plant drains, overflow from the ash reservoir, etc. The water lost through evaporation, blowdown, etc., will amount to approximately 16,000 gpm. The basin could have possibly a one-day detention time, after which the water would receive pH adjustment and/or desalinization and be discharged to the watercourse. However, the discharge would have to be monitored to be certain the dissolved solids content complied with E.P.A. stream standards, which are quite restrictive in the Big Horn and Little Big Horn River basins.

Ash Reservoir - A reservoir similar to that described under Complex A could be used for ash disposal. However, it would be only about one-fifth the size of that facility's reservoir. As much as 130,000 pounds of ash per hour could enter the pond. A reservoir approximately 360 to 380 acres in area and up to 50 feet in depth could contain the waste sludge from 50 or more years of operation. As an alternative after dewatering, the ash could be returned to the mine for disposal in much the same manner as described for Complex A.

Power Substation - Each power-generating unit will be connected to a transformer in the power transmission switchyard and substation. The area will be adjacent to the plant building and fenced for safety. Transmission lines will then carry the current to the customers, by way of distribution systems.

Water Requirements - The water required for liquefaction, hydrogen production, and power generation will be greater than that used for the gasification plant, i.e., about 13,000 gpm for liquefaction; 23,000 for H production; and 16,000 for power generation, for a total of 52,000 gpm or 115 cfs. Again the only source for a quantity this great is the Yellowtail Reservoir or the Big Horn River below the dam. To transport the supply to a location in the southeastern part of the reservation, a pipeline of 55 miles would be required to deliver the water to Complex B.

Gasoline Transportation - It is assumed that the gasoline would be transported by pipeline to the market. Product pipelines now carry petroleum products from refineries in Billings to markets throughout the Pacific Northwest and east to North Dakota. Presumably a connection to these lines would be advantageous.

Plant and Mine Staff - The liquefaction and power plant complex will require about 1,930 people for operation, and the mine will require a staff of about 675 people.

Complex C

Complex C, located in the southeastern section of the Ceded Area, will be a smaller industrial-mining complex. Expansion of the low-level strip mine to a 15,000,000-ton-per-year capacity and the opening of a 5,000,000-ton-per-year strip mine nearby is assumed. In conjunction, a gasification and power generation plant will utilize the additional 10,000,000 tons of coal produced under this high level of development.

Mines - The large mine will be similar to those described under Complexes A and B, except that it will be only half as large. The small mine will be similar to the existing mine now in operation on Tract 3 in the southeastern portion of the Ceded Area. The terrain is less rugged than that for Complex A and should be more amenable to reclamation. Transportation access to the area by rail or paved road is fairly well developed at present and might require only minor expansion. In most respects, these and other facilities will be similar to those of the low-level Ceded Area development.

Coal Seams - Mineable coal seams in the Ceded Area include the Rosebud-McKay and Robinson seams on Tracts 2 and 3 and the Rosebud-Stocker Creek and Robinson seams on Tract 5. These seams vary from about five to 30 feet in thickness, while the intervals between the seams vary from seven to 65 feet. The total coal seam interburden thickness may approach 200 feet. The mining of one or more seams for a total of up to 50 feet of recoverable coal is assumed.

Gasification Plant - The gasification plant would be one utilizing the CO_2 acceptor process proposed for Complex A. It is anticipated that the plant would produce close to 300,000,000 scf per day of synthetic natural gas from an annual strip mine production of 10,000,000 tons of coal.

Gasification Plant Resource Needs - Water: To operate a gasification plant of this size, a water supply of approximately 16,000 gpm is required. This rate of flow is equivalent to an annual consumptive water use of about 25,000 acre feet. Process, cooling and blowdown water requirements are included in this figure. A reduction could be effected if dry cooling facilities or other forms of recirculation were utilized. The nearest available sources of water would be the Bighorn River and the Yellowstone River. A pipeline approximately 25 to 35 miles long with suitable pumping facilities would be required to utilize these sources.

Dolomite: A plant using the CO_2 acceptor process will require 600,000 tons of dolomite annually.

Power Generating Plant - As with the Complex A gasification plant, an excess of about 100,000 pounds per hour of high-pressure 1,000° F steam and 1,000,000 pounds per hour of low-pressure 350° F steam would be produced. Installation of a 40,000 kilowatt steam turbine power generating plant for utilizing this excess steam energy would make the industrial complex self-sufficient in electrical power and allow the scale of the excess power to a power transmission company.

Plant and Mine Staff - It is anticipated that about 650 employees will be needed to staff the gasification power generation plant, and that an additional 225 personnel will be required for the larger mine, with possibly 112 for the smaller mine.

Cooling Pond and Ash Reservoir - Facilities similar to those proposed for Complex A could be utilized. However, their size would be only about one-third as large.

Gas Transportation - Installation of a pipeline for conveyance of the synthetic natural gas to an existing natural gas pipeline distribution system would be required, as well as a large compressor station adjacent to the industrial complex. An existing natural gas pipeline is located about 30 miles north of Complex C.

CHAPTER II

THE
EXISTING
ENVIRONMENT

CHAPTER II

THE EXISTING ENVIRONMENT

The Crow Indian Reservation and its Ceded Area lie in south central Montana, the southern border of the reservation being the Montana-Wyoming border. It is an area richly endowed with both esthetic and productive resources, and the history of its transformation from the fruitful hunting and gathering ground of the aboriginal Crows to its present agricultural economy is varied and interesting.

THE HUMAN ENVIRONMENT

The Cultural Heritage

The culture of the people, both Indian and non-Indian, in the Crow coal resource area is highly influenced by generations of living in close association with nature. It is the often expressed opinion that, among both races, the local people have developed a way of life and a system of values that reveres land and open space.

The culture of the Crow Indians and the heritage of their people is more accurately described by a tribal member:

> The Crows are of Siouan origin but had broken away from their ancestral group (Hidatsa) and settled along the valleys of the Yellowstone and Big Horn long before the coming of the white man. This tribe was originally called Absarokee which means 'Children of the large beaked bird,' probably a raven. The Absarokee Tribe evolved through several stages of cultural development. The early ancestors who lived in the eastern forests practiced agriculture and achieved a fairly high level of civilization. As they were pushed westward, they gradually became more and more dependent upon the hunt. By the time of their settlement on the plains, their agricultural pursuits were limited to the planting of corn and squash. Soon after

their separation from the main tribe (probably somewhere in what is now North and South Dakota), the Absarokee abandoned agricultural ways and became a nomadic people.

Religion also has had a profound influence on the Crow people's culture. "The old time Crow Indians recognized a supreme being whom they called 'First Maker' but did not worship it directly. They sought its benevolence and favor through the worship and devotion to various animals and objects of nature which were regarded as possessing supernatural powers given them by the 'First Maker'." Although virtually all Crow Indians are now heavily influenced by the Christian religion, elements of their old time beliefs in natural forces still prevail.

Early associations with nature and the tribe's movement throughout the land have influenced the cultural values of today's Crows. A maxim states that "Personal gain and the accumulation of private wealth has little prestige value in the Crow communities." And while the culture of the non-Indians in the area has seemed to vary greatly from that of the Crows, it developed many similar traits. The basic regard for land dominates the life of both groups.

History and Archaeology

Historical and archaeological data thus far gathered indicate that both prehistoric and historic tribes left traces of their cultures on the Crow Reservation and the Crow Ceded Area. Archaeological findings include mainly temporary and minor sites, but no durable or significant ones.

The Wolf Mountain range along the eastern fringe of the Crow Indian Reservation tapers off at Little Thompson Creek, and from there northward the land is moderately rolling to quite rugged, with intermittent stands of ponderosa pines on high points, ridges, and north-and northeast-facing slopes. This mountain range covers a north-south strip roughly two townships wide and five long, or an area about nine by 30 miles. Evidence gathered so far indicates that prehistoric and historic native people utilized the mountains for summer food gathering and intertribal activities. The area north of Little Thompson Creek was used mainly for buffalo hunting.

History - The Absarokee or Crow was the first of the modern Plains Indian tribes to migrate into this part of the Northwest. A small group separated from its ancestral tribe in what is now the State of North Dakota about 1600 to 1625, and came westward looking for a good land which their chief (No Vitals) said the Great Spirit had promised them. The band of about 400 people roamed and wandered around the Northwest for nearly a century before arriving at the headwaters of the Missouri and Yellowstone Rivers and finally declaring the area to be the "promised land indeed."

Thus began the founding of an empire. By mid-1700's, the Absarokee had already explored and established themselves as rightful owners of a hugh geographical area bounded on the east side by the Powder River, on the south by the lofty Wind River Mountains, on the west by the Rocky

Mountains, and on the north by the Missouri, the "Big River" as it was called by the Crows. With acquisition of the horse and white man's gun, the Crows were well able to protect and hold their land from the surrounding tribes as well as to wage aggressive warfare in enemy territories.

Traditionally the Crows have always claimed the Wolf Mountains (Wolf Teeth) as part of the "Crow Country" by reason of discovery and occupation. The Fort Laramie Treaties of 1851 and 1868 give legality to this claim by including the Wolf Teeth as part of the large area assigned to the Crow Indians. This range, forming the summit and divide of the Rosebud Creek and Little Bighorn River drainages, has always been a part of the "heart land" of the Crow Country and thus has played an important part in the history and affairs of the Crow people.

The Wolf Mountains are neither high nor rough, but are softer, more gentle, and more habitable than most mountain areas. They have always been a good big game habitat, with their luxuriant grass and many good streams and springs; wild fruits and edible roots flourish for the picking during the summer. In short, this was one of the best and most dependable game hunting and food gathering grounds for the Crows. North of the mountains from Little Thompson Creek to the present north boundary of the reservation, and even beyond to the Yellowstone, there was the open buffalo-hunting country.

By mid-1880's, the tribes from the east (Sioux, Cheyenne, and Arapaho) began to seriously encroach upon the eastern frontier of the Crow Country. As these tribes were pushed progressively westward by the expanding American frontier, intertribal warfare, once a somewhat dangerous but mainly status-building game among Plains Indian warriors, had become serious. The Sioux and Cheyenne, usually allies, considered conquering the Crows in order to increase their fighting force and to use the Crow land as their last fortress in resisting the white man. Two such attempts at conquest were made in the latter 1860's at Pryor Creek. Thus by the mid-1860's, the earlier buffer zone character of the Wolf Mountains and the northern foothills in the days of routine intertribal war had changed to that of a serious battle ground. The Wolf Mountains finally became the last natural barrier forming the eastern border of the shrinking Crow empire. Here many ambushes and pitched battles took place. Hill-top lookouts, fortifications, and battlefield markers now mutely attest to the military character of the Wolf Teeth Mountains.

The Crow Indians have always expressed sentimental attachment to these mountains. The tribal annuals are rich in military and other notable tribal history which was made here over the years. Today members of the tribe own and have heirship interests in allotments of land along the entire east border of the reservation. The Crow Tribe has been trying to sue the Federal Government for survey errors that resulted in the loss of use and income from a strip of land ranging in width from a few rods to over one mile along the entire eastern border from the Wyoming-Montana line to the Yellowstone River, an area containing over 5,000 acres.

The non-Indian history of this part of the Crow Country has been reliably recorded in accounts of the early trappers, fur traders, explorers, "squawmen", military people, Indian agents, etc. Francois LaRogue and the La Verendrye brothers of the Hudson Bay Co., Lewis & Clark, Jim Bridger, Jim Beckworth, and many others mentioned the Wolf Mountains and adjacent landmarks such as the Tongue River, the Rosebud, Little Bighorn, Tullock and Sarpy Creeks. Even Theodore Roosevelt hunted in the Wolf Mountains in the 1880's and described them as the main home of the grizzly bear.

The Crows made a series of land cessions to the Government in the 1880's and eventually moved eastward into the diminishing portion of the once vast Crow Country. The agency headquarters was established at its present location in 1884. Here the "civilizing" program or process was earnestly set in motion by the Government.

It was soon recognized that the entire area east of the Little Bighorn and the Lower Bighorn Rivers was a great livestock grazing country. By 1890, large sheep and cattle companies were already on the reservation competing for grazing permits. Since that time, the non-Indian history of the area deals mainly with the activities of livestock people. Big outfits like the Finlynson-Johnson Sheep Company, Spear Brothers Cattle Company, Cort Sheep Company, Faddis-Kennedy, Antler Land Company, Scott Land & Livestock, and many small individual livestock operators have left their marks. Today old cow camps, roundup camp grounds, drive lines, and corrals, all bear names reminiscent of their past such as the Spear Camp, Wild Horse Camp, Tartar's Trap, Cook Stove Canyon, and naturally ranches like the OW, SU, 40 Mile, Bar V. Some of the old barns, corrals, line shacks, and dugouts are still discernible, and a few are still in use. But most are fast deteriorating and are being ravaged by antique and relic hunters.

Archaeology - Generally speaking the archaeology of the area is little known. Arrowhead collectors have kept away from the Wolf Mountains since the heavy vegetation discourages surface hunting of artifacts. Professional archaeologists have made no attempt to come into this part of the reservation, nor have they been invited to do any work by tribal officials.

However, since 1970, coal prospecting and impending strip mining operations along the entire eastern border of the reservation have created interest in the archaeology of the area. Final archaeological surveys have been made in the coal resource area. These include:

> 1971 & 1972. University of Montana in the Upper Sarpy & Colstrip areas adjoining the northeast corner of the reservation for Westmoreland Resources, Western Energy, and the Burlington-Northern Railroad. Eight sites were found in the Westmoreland Crow Lease area, consisting of vision-quest cairns, rock art, temporary rock shelters, lookouts, etc., but nothing of real significance requiring full excavation. In the Colstrip area, about 20 miles east of the reservation, five similar sites were found.
>
> July-August, 1971. University of Montana for the Decker Coal Company's immediate mining area about five miles northeast of the southeast corner of the reservation. Here four good sites (bison trap, hearth site, lookout, and fortification) were located and studied. A fine Eden Valley point (8000 B.C.) was also found on the surface.
>
> July-August 1972. Two teams, one from University of Montana and one from University of North Dakota, worked the area between Birney and Decker, Montana, from five to fifteen miles northeast from the southeast corner of the reservation. The North Dakota team, headed by Mel Barnett and Tom Larson, listed 22 "occupation" sites but nothing unusual or significant to warrant further work. The Montana team headed by T. W. Haberman, listed 44 sites consisting mainly of 22 lithic areas or where stone artifacts were made, six occupation sites, two bison traps, three tepee ring sites and the usual lookouts and miscellaneous rock structures. The narrative reports on these two surveys are not yet available.

July 1972. University of Montana (Dale and Lynn Fredlund) for Shell Oil Company in its Crow Reservation coal prospecting area. The survey area contained approximately 3,750 acres (5.86 square miles) on all or parts of sections 22, 23, 25, 26, 27, 28, 34, 35, and 36 of Township 9 South, Range 38 East, Big Horn County, Montana. This is only a small part of the approximately 138 square miles on which Shell has a prospecting permit with option to lease. Thus, at best, this survey is a concentrated "spot check" and useful mainly as a bench-mark in gauging the archaeological potential of the southeast portion of the Crow Reservation. Judging from the character of the land, archaeology should be rich here. The high and more open (less timber and brush) southern fringe of the Wolf Mountains is good game and wild fruit country and certainly has been attractive to ancient and historic peoples. This survey revealed 12 prehistoric sites. Six were test-excavated and two recommended for further excavation. These sites include 2 rock art, 3 lookout-occupation sites, 2 creekside occupations, 1 bison kill, and 1 rock shelter. These 12 sites were named and assigned numbers consistent with the Smithsonian trinomial system. Lithic areas (rock chipping stations) will limited debris were not assigned numbers. The artifacts recovered consisted of the usual arrow and spear points, knives, scrapers, and miscellaneous tools. One McKeon-type point (3000 BC-AD 500) gives considerable cultural time depth to the area.

August-September, 1973. Montana State University (John Darrock and Bob Peterson with a team of Crow college students) for Gulf Resources, Inc. in its coal prospecting area. This area of about four townships or 130 square miles in the south-central sector of the east border area of the Reservation constitutes the very heart of the Wolf Mountains range. The team conducted a "hotspot checking" type of surface survey and evaluation. This means that the surface search was concentrated along drainages at low and median elevation with intermittent survey of the most prominent and exposed uplands. This cursory survey of only two weeks identified 70 locations of prehistoric interpretive significance. Ninety percent of the sites, mainly occupation and lithic areas, were found along stream terraces of such creeks as Gray Blanket, Cache, Spring, Indian, and some tributaries of Owl Creek. At these sites such artifacts as scrapers, knives, arrow and spear points, and miscellaneous stone tools were found in abundance. Chronologically, these range from historic to middle prehistoric period. Several Pelican Lake, First View, Old Woman's, and Avonlea points were found; McKeon and related artifacts, vision quest cairns, hilltop lookouts, rock writings, and other rock structures were also found. Each location was named and assigned a number consistent with the Smithsonian unform site designation system (24BH1801 through 24BH1870).

The composite picture, based on interpretation of the data thus far gathered, clearly indicates that prehistoric peoples inhabited the Wolf Mountains and surrounding areas long before the coming of the historic tribes, and that these early inhabitants had certainly developed their own ecosystems here. It appears that prehistoric occupation began at least 8,000 years ago, as evidenced by the Eden Valley, McKeon, Pelican Lake, and other Middle Prehistoric Period artifacts which have been found.

Reservation History

The transformation of the area now known as the Crow Reservation and its Ceded Area from the fruitful hunting and gathering grounds of the aboriginal Crows to its present agricultural economy is complex.

The original 1851 Treaty of Laramie gave the Crows a reservation of 38,000,000 acres. An initial reduction to 9,000,000 acres by the U. S. Government was followed by subsequent cessions until today the Crow Reservation encompasses less than 2,300,000 acres.

The initial non-Indian settlement in Big Horn County occurred during the 1880's, with continuing increases in non-Indian population until 1940. Hardin, the county seat, was settled in 1907, and Big Horn County was created in 1913 from parts of Rosebud and Yellowstone Counties. This influx of non-Indians resulted in the alienation of Indian owned lands until today Indians own only 1,500,000 acres.

The Crow Ceded Area came into being with the Congressional Act of April 27, 1904 (33 Stat. 352), which ratified an agreement with the Crow Indians and ceded the northern portion of the reservation. Proceeds from the sale of the ceded lands to settlers were to be credited to the Indians. Indians living on the ceded lands were permitted to remain and receive allotments on the lands they were occupying or to move to the reduced reservation and receive payment for their former lands and the improvements thereon.

After some 54 years on the market, all vacant and undisposed ceded land was restored to the Crow Tribe by Congress in the Act of May 19, 1958 (72 Stat. 121). These lands were returned to trust status and all coal rights that were retained by the U. S. Government when the land in the Ceded Area was patented to the settlers, were also returned to Crow Tribal ownership. The Crow coal rights in the Ceded Area now total just over 150,000 acres, of which 45,113 acres are in the Crow resource area involved in this study. These coal rights are owned in trust by the Crow Indians and are administered for the Secretary of Interior by the Bureau of Indian Affairs.

Surface ownership in the more than 1,100,000 acres in the Ceded Area includes approximately 9,000 acres of tribal land, 17,000 acres of allotted land, 45,000 acres of State land, and over 1,000,000 acres of private fee land. In other words, over 90 percent of the Ceded Area consists of fee land, while less than three percent is in Indian ownership. However, Indians own 14 percent of the coal resources.

The People Today

At present the coal reserve area is rural with a population mix of Indian and white. Big Horn County, in which the major portion of the reservation lies, was 38.9 percent Indian in 1970, and the Crow Reservation proper was 56.1 percent Indian. Although this is an agricultural area, the Indians do not participate to a large extent in the agricultural economy, and a high percentage of their land is in fact leased to non-Indian operators.

The Crow Reservation, near Interstate 90, lies 27 miles north of Sheridan, Wyoming, and about 50 miles east of Billings, Montana, (1970 population 10,856 and 71,197 respectively) which provide many services not available locally. Billings is the major trade center and provides full medical and other services for a large section of southeastern Montana and Northern Wyoming.

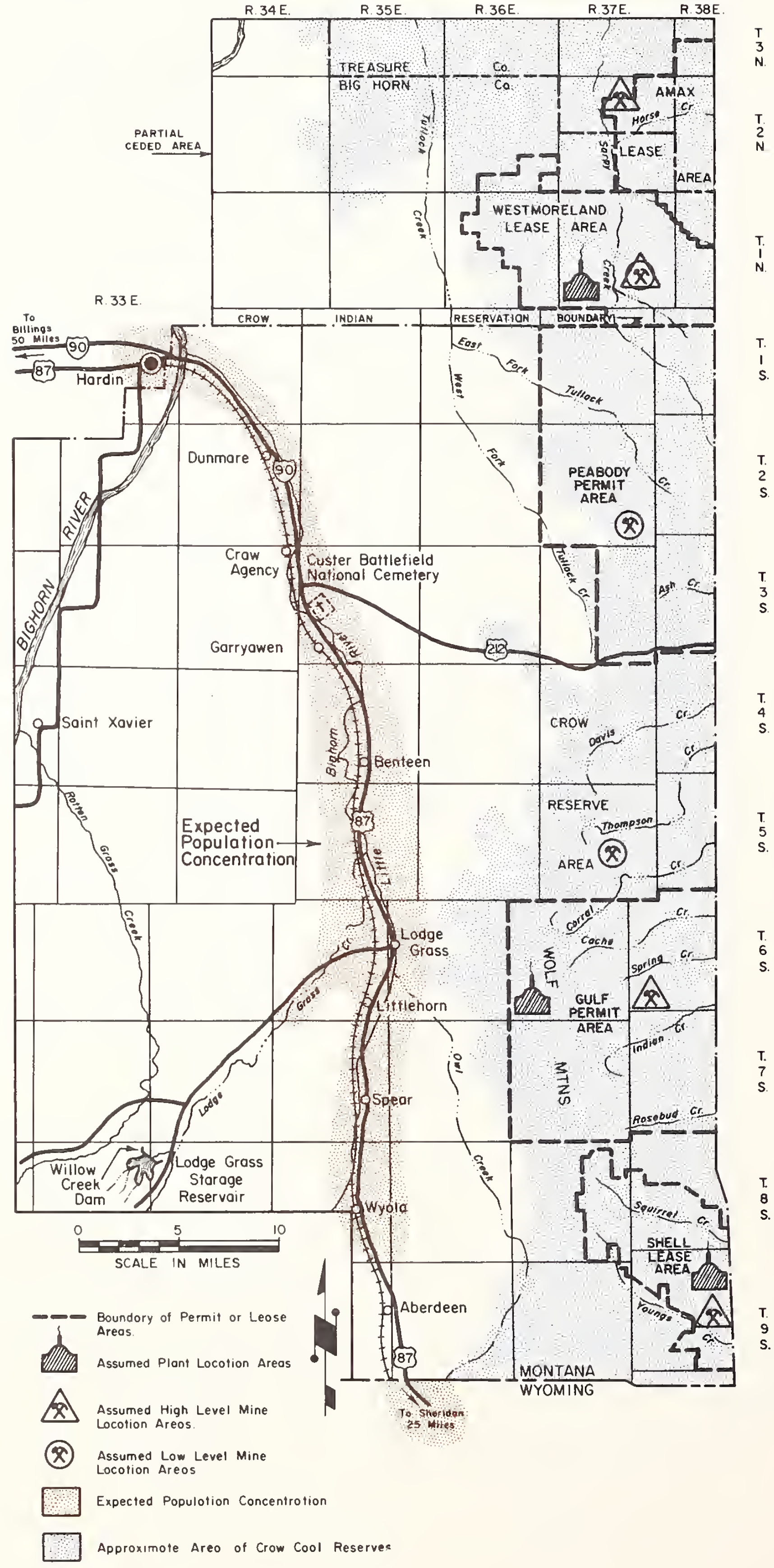
The reservation population, both Indian and non-Indian, lives mainly in the small towns and valleys. Although many Indians live on their land, not many are engaged in farming and ranching, the main occupations of the white population.

The towns and communities on or near the reservation which will probably feel the greatest impact from coal development are Hardin, Crow agency, Lodge Grass, and Wyola due to their close proximity to the coal deposits. Other communities on the reservation which will be less affected by the coal development are St. Xavier, Fort Smith, and Pryor. Billings, Hysham, Forsyth, and Sheridan also will feel impacts from such development.

MAP 3

AREA MOST LIKELY TO BE AFFECTED BY COAL DEVELOPMENT

CROW INDIAN RESERVATION AND CEDED AREA



Hardin (1970 population 2,733) is the Big Horn County seat and is immediately adjacent to the impact area. It is the main trade center for the Crow Reservation where many Indians attend the public schools. Hospital, truck and rail freight, banking, auto and equipment dealers, bulk fuel distributors, public accommodations and other facilities are available.

Three communities within the reservation will feel the greatest impact from coal development. The town of Crow Agency (1970 approximate population 1,000), where the Crow Tribal headquarters, BIA Agency, and Indian Health Service Hospital are located, is a predominantly Indian community with most of the non-Indians being government employees. A service station, elementary school, grocery store, and small cafe are the only public facilities available. Two modern motels, including the Sun Lodge complex owned by the Crow Tribe, are located about two miles south of town near Custer Battlefield.

Another Indian community which is likely to feel a major impact is Lodge Grass (1970 population 806) where the population is just over half Indian. It has a grade school and high school, but other service facilities are limited to an REA office, grocery stores, a general merchandise store, a small hotel, two garages, a cafe, liquid propane gas suppliers, appliance store, post office, lumber yard, and several service stations.

The small reservation community of Wyola (1970 population 125), which may also feel a significant impact, has a public school for grades one through eight, a cafe, post office, and a service station.

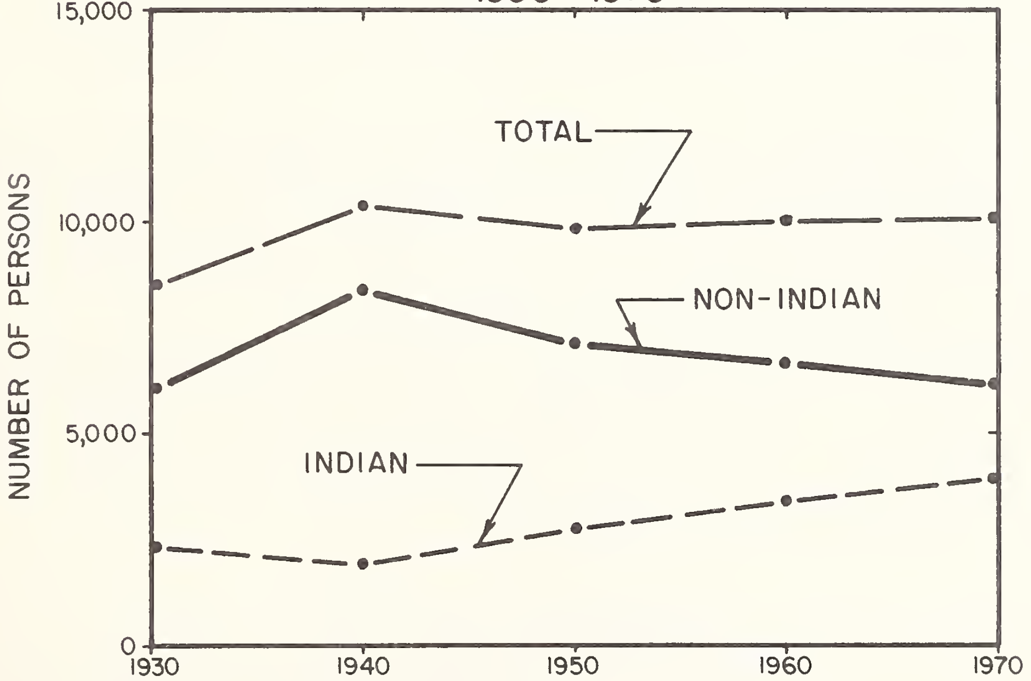
Two non-reservation communities near the Ceded Area may feel a substantial impact from any coal development in the Ceded Area. Hysham (1970 population 373) is the Treasure County seat and a local trade center. It has a high school, grocery stores, garage, restaurant, service stations, bars, and an equipment dealer. Forsyth (1970 population 1,873) is the Rosebud County seat and a trade center for the surrounding area. It has a variety of stores, bank, hotel, restaurant, auto and machinery dealers as well as educational and health and other facilities usually associated with a full convenience shopping center. It is currently experiencing a rapid population growth which is putting a severe strain on housing and community facilities.

The total population of Big Horn County, in which most of the coal areas are located, has remained at about 10,000 over the past 40 years. The 1970 U.S. Census reports a population of 10,057.

Census figures indicate a Crow population of 3,161 living within the boundaries of the Crow Reservation, or approximately 81 percent of the total Big Horn County Indian population. Outside the reservation boundaries, the towns of Hardin and Busby contain most of the county's remaining Indian population. The Crow Ceded Area also has about 100 Indian residents.

The non-Indian population in the county has declined from 8,423 in 1940 to 6,140 in 1970 (-27.1 percent) following an increase during the 1930-1940 decade. On the other hand, the Indian population has shown significant increases every decade since 1940. The Indian population increased from 3,334 to 3,917 (+17.5 percent) during the 1960-1970 decade, while the non-Indian decreased from 6,673 to 6,140 (-8.0 percent) during the same period. 1/ in 1970, the Indian population in Big Horn County was 38.9 percent of the total population. If the present trends continue, Big Horn County will have a population evenly divided between Indian and non-Indian in 10 to 15 years.

FIGURE 6
POPULATION TRENDS
BIG HORN COUNTY
1930 - 1970



SOURCE : U.S. Census.

1/ Tribal estimates based on enrollment statistics for 1974 indicate a higher Crow resident population at somewhere over 4,000.

Table 5 shows population trends for two of the principal towns, one on the reservation and one immediately adjacent.

Table 5 Major Population Changes 1940-70

	1940	1950	1960	1970
Lodge Grass	839	536	687	806
Hardin	1,886	2,306	2,789	2,733

Both Lodge Grass and Hardin remained relatively stable over the 1940-1970 period, with Lodge Grass decreasing by less than one percent and Hardin increasing over 14 percent. However, during the last decade, Lodge Grass increased by 17 percent and Hardin decreased by two percent.

Age Distribution - An analysis of the age composition of a population is important for the planning of such program requirements as education, housing, and work force projections.

Population numbers and percentage composition by age groupings of the Indian people on the reservation compared to the non-Indian people in Big Horn County is shown in Table 6.

Table 6 Age Distribution

Age	Indian On Reservation		Non-Indian Big Horn County	
	number	percent	number	percent
0 - 14	1,378	43.6	1,848	30.1
15 - 29	819	25.9	1,314	21.4
30 - 44	468	14.8	1,019	16.6
45 - 59	316	10.0	1,112	18.1
60 - 75	139	4.4	620	10.1
75+	41	1.3	227	3.7
Total	3,161	100.0	6,140	100.0

Source: U. S. Census

By and large both the Indian and non-Indian population are quite young. However, the Indian population is significately younger compared to the non-Indian, with 43.6 percent of the Indians 14 years of age or younger compared to 30.1 percent of the non-Indians. On a broader age distribution, 69.5 percent of the Indians are under 30 years of age compared to 51.5 percent of the non-Indians. Conversely, only 5.7 percent of the Indians are 60 years of age or older compared to 13.8 percent of the non-Indians.

The Economy

The present economic base of the Crow coal reserve area is agriculture, particularly in the coal development area. Government employment also plays a major part in the economy, with Bureau of Indian Affairs, Public Health Service, National Park Service and Bureau of Reclamation having payrolls within the reservation and other Federal, County, City and Tribal entities providing payrolls on and adjacent to the reservation. There is a very small industrial payroll in the area.

The economy of the proposed mining area is predominantly cattle ranching. The cattle graze these areas most of the year and receive supplemental feed in the winter. Feed crops and some small grain cash crops are grown throughout the area where the soils are suitable.

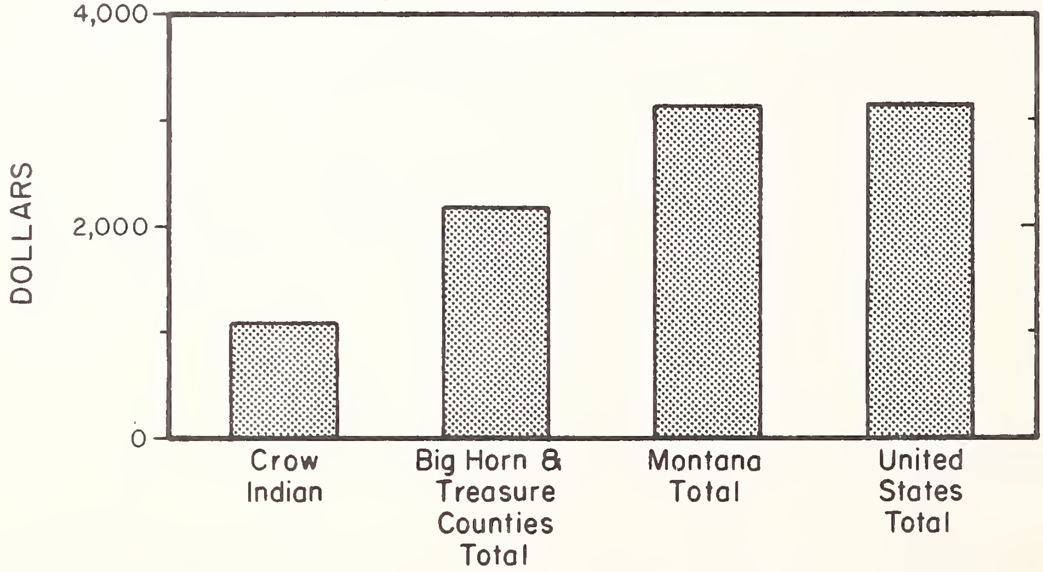
If coal mining does not take place, the economy likely would not change appreciably from that of today. The population would probably continue at about the present level, with the Indian population increasing and the non-Indian decreasing as the farms and ranches consolidate into large units and the service industries migrate to larger urban centers like Billings.

Income - With agriculture dominating the economy, the census data indicates family income for Big Horn County was made up of $12,824,500 from wages and salaries (including wages for farm hands), $3,561,300 from farm self-employment, and $1,206,900 from non-farm self-employment. Family income in the Sarpy Census Division in Big Horn County, a census division typical of the Crow coal development area, consisted of $486,200 from wages and salaries (including wages for farm hands), and $307,700 from farm self-employment.

Income, expressed on a per capita basis, is shown graphically in Figure 7.

FIGURE 7

PER CAPITA INCOME
CROW INDIAN, BIG HORN AND TREASURE
COUNTIES, MONTANA, AND UNITED STATES



Income levels of Big Horn and Treasure County residents are lower than those of Montana or the nation, while the income of the Indians on the Crow Reservation is substantially lower still.

Another indication of income is a comparison of poverty levels. According to the 1970 U.S. Census poverty index, 39.4 percent of resident Crow Indian families are in poverty. By comparison, 21.4 percent and 17.2 percent of all families in Big Horn County and Treasure County respectively are below the poverty line, while the figure is 10.4 percent for all of Montana. The on-reservation median family income for the Crow Indians in 1969 was $5,260 compared to $8,210 for the white families on the reservation. [1/]

Labor Force and Employment

Table 7 (page 60) shows that in 1970, of 1,686 Indians and 4,814 whites 16 years or older, 38.9 percent of the Indians and 58.3 percent of the whites were in the labor force. There were 340 males and 690 female Indians not in the labor force, and 432 white males and 1,577 white females in the same category. For census analyses, the labor force is defined as those 16 years old or older employed or actively seeking work. Many of those not in the labor force are 65 years old or older, are housewives, or are students. If bona fide employment opportunities existed, a considerable number of those not presently in the labor force probably would accept work.

[1/] The nation-wide poverty threshold for a farm family of four headed by a male was $3,197, while for a family of 6.16 (the average size of Crow families in poverty) the index was approximately $4,500.

Table 7 Labor Force and Employment 16 Years Old and Older 1970 - On Reservation and Hardin

	Indian	Non-Indian
16 Years Old and Older		
Male	780	2,382
Female	906	2,432
	1,686	4,814
Total Labor Force	656	2,805
Percent total population in labor force	38.9	58.3
Population not in Labor Force		
Male	340	432
Female	690	1,577
	1,030	2,009
Employed		
Male	385	1,886
Female	201	826
Unemployed		
Male	55	64
Female	15	29
Unemployment Rate		
Male	12.5	3.3
Female	6.9	3.4

Source: U. S. Census

The March 1973 BIA Labor Force Report on the Crow Reservation, using somewhat different definitions, reports a labor force of 1,249, nearly twice that reported by the U. S. Census. Employment rates were also much lower with 886 or 70.9 percent employed while unemployment rates were much higher with 363 or 29.1 percent unemployed. Of the unemployed, 190 Indians or 15.2 percent were actively seeking work. Over the past 10 years, the BIA Labor Force Reports have repeatedly shown the unemployment of the Crows to be as high as 30 percent, with approximately one-half of these actively seeking work.

Employment by Occupation

As shown in Table 8, the largest occupational category for Indian males is operatives, including transport, a dominant occupation in coal industries. About one quarter of the employed Indian male work force (23.9 percent) is in the operatives category. The number of Indians in the Indian professional, managerial, and kindred worker category is almost on a par with the whites: 21.3 percent compared with 22.9 percent. The number of Indians working for the BIA and Indian Health Service partly accounts for this relatively high Indian figure.

Table 8

Employment by Occupation
On Reservation and Hardin
Males 16 Years Old and Older - 1970

	Indian		White	
	number	percent	number	percent
Professional, Managerial, and Kindred Workers	82	21.3	431	22.9
Craftsmen, Foremen, and Kindred Workers	39	10.1	307	16.3
Operatives, including transport	92	23.9	176	9.3
Laborers except farm	53	13.8	100	5.3
Farmers and Farm Managers	29	7.5	431	22.8
Farm Laborers, except unpaid and Farm Foremen	68	17.7	188	10.0
Other	22	5.7	253	13.4
Total	385	100.0	1,886	100.0

Source: U. S. Census

Quite a large percentage of the whites (22.8 percent) are employed as farmers and farm managers, compared to the Indians (7.5 percent) in this category. However, agriculture plays an important part in Indian employment with 25.2 percent employed as farmers, farm managers, or farm laborers.

The March 1973 BIA labor force report lists occupational sectors a little differently, but the three highest employment categories for Indians were Agriculture (31.5 percent), Government (26.5 percent), and Commercial Industries and Tourism (17.6 percent).

Public and Private Service

Education - Educational facilities on and adjacent to the reservation are provided by public schools, one Federal Indian school contracted to the Northern Cheyenne Tribe and two private schools. These are described in Table 9.

The four schools listed at the top of Table 9 have 1,438 students or 72 percent of all students in the county. These are the schools located on or near the coal reserve area that are expected to feel the major impact from coal development. All of the schools are open to both Indian and non-Indian students, with all four schools in the impacted area having a high representation from both groups.

Crow Indian educational attainments are significantly lower than the levels for Big Horn County and the State of Montana. The median educational level of school completed by Crow Indians 25 years of age and older is 9.4, compared to 11.8 for the Big Horn County total and 12.4 for the State of Montana.

Table 9

Big Horn County School Systems
October 1973

Name	No.	Class 3/	Elementary Certified Staff	Elementary Students	High School 1/ Certified Staff	High School 1/ Students
Hardin	16	(3)	2	27	--	--
Hardin	17H & 1*	(2)	55	944	63 2/	792
Lodge Grass	27 & 2*	(3)	26	361	28	163
Wyola	29	(2)	10	106	--	--
Decker	1	(3)	1	9	--	--
Kirby	17K	(3)	1	14	--	--
Pryor	2	(3)	6	70	--	--
Busby	Tribal	(3)	8	220	13	110
St. Charles, Pryor	Private	(3)	6	61	--	--
St. Xavier	Private	(3)	10	188	--	--
Total			251	2,000	75	1,065

1/ Includes Junior High School
2/ Includes 14 serving multiple schools
3/ Class 2 indicates districts with population of 1,000 to 6,500. Class 3 indicates districts with population of less than 1,000.

*High School District Number.

Housing

The housing inventory on and adjacent to the Crow Reservation is presented in Table 10.

Table 10 Housing Units - Indian and Non-Indian
Crow Indian Reservation, 1970

	Indian	Non-Indian	All Vacant	Total
	number	number	number	number
On Reservation				
Owner occupied	437	411		848
Renter occupied	99	341		440
Vacant	--	--	169	169
Total	536	752	169	1,457
Adjacent to Reservation				
Owner occupied	18	978		996
Renter occupied	36	467		503
Vacant	--	--	97	97
Total	54	1,445	97	1,596
On and Adjacent to Reservation				
Owner occupied	455	1,389		1,844
Renter occupied	135	808		943
Vacant	--	--	266	266
Total	590	2,197	266	3,053

Source: U. S. Census

Housing needs in the coal resource and immediate areas are presently acute, with an estimated 800 housing units required for Indians alone. Much of the present need is being met by mobile homes in all communities of the county.

Utilities

The Montana Power Company and Big Horn Electric Cooperative provide electric service to the reservation area. Montana Power has two 69-KV and one 230-KV transmission lines passing near Hardin.

Montana-Dakota Utilities Company provides natural gas to the area with its twelve-inch Worland-to-Cabin Creek line passing near Hardin. A three-inch lateral serves Crow Agency, with the remainder of the reservation area being without natural gas service.

Law and Order

Law and order on the Crow Reservation is maintained by the BIA and the Crow Tribe. This includes an agency special officer, a criminal investigator and a captain of police, all employed by the BIA. Eight additional police officers hired by the Crow Tribe serve the various Indian communities. The Crow Tribe also employs six support personnel including judicial, detention rehabilitation and administrative specialists and provides appropriate facilities for such activities.

Big Horn County has a sheriff and three deputies, as well as a jail at the county seat. Hardin, which employs a city police chief and four police officers, maintains a city jail. Finally, the town of Lodge Grass has a city marshal and a small detention cell.

Health Services

The Crow Reservation's health facilities for Indians are centered at Crow Agency, where a 34-bed hospital complete with a staff of five physicians is operated by the Indian Health Service. Health facilities include a full array of in-patient and out-patient services, including nursing, laboratory, pharmacy and dental facilities and staff.

A 16-bed hospital with a 34-bed nursing home wing is located in Hardin. It has a full nursing and technical staff, but only one resident medical doctor. The community is attempting to obtain the services of another physician. Hardin also has two dentists and visiting services of two optometrists.

Billings, Montana has two large hospitals and a very extensive medical staff, including doctors of medicine in essentially all specialties. Sheridan, Wyoming also has extensive medical facilities, including a veterans hospital.

Business Services

Hardin provides a central, full convenience shopping center for the coal resource areas with seven food stores, six motels, one hotel, and seven automotive and implement dealers. The other communities on the reservation have minimal trade and shopping facilities essentially limited to food and gasoline.

Billings, Montana and Sheridan, Wyoming are the major off-reservation trade centers and are capable of providing the full array of service facilities required for mine development and servicing an anticipated population increase.

Intercultural Relationships and Jurisdiction Issues

The socio-economic pattern of the Crow Reservation is set in the traditional Montana rural setting with its economic base being a combination of dryland and irrigated crops and beef cattle production. This rural setting has established a cultural complex in which the two ethnic groups have found a common ground for economic subsistence and social accomodation.

The Crow Reservation is not an ethnic island where essentially all of the residents are Crow Indian. This is particularly true in the Little Bighorn Valley and its tributary valleys where the greatest impact from residential and commercial development is anticipated. Here the amount of Indian land and non-Indian land is nearly evenly divided and, although the number of Indians definitely exceeds the number of non-Indians, the mix is evident in every community and in nearly every facet of community life.

Jurisdiction on non-Indian land in this area and many of the social services are provided by non-Indian institutions. Conversely, jurisdiction of Indian lands and a number of socio-economic institutions (e.g., the irrigation project) are dominated by Indian interests. There has been a reasonable, if informal, accommodation developed over the past six decades between these two interests.

For instance, although the determination of jurisdiction is not entirely clear within the boundaries of the reservation and such items as severance taxes have been questioned by the tribe as to their legality, there have been no major disputes. The law and order system, which is essential to the orderly growth and development of any community, is a good example of this accommodation. Presently, law enforcement people from tribal, county, State and Federal levels are cross-deputized and function in a cooperative effort to maintain law and order.

While the tribe has no jurisdictional and land use controls over areas outside the reservation (except possibly in the Ceded Area), it does claim jurisdiction for such controls within the reservation boundaries. Jurisdiction by the State, county and local governments regarding land use controls on the reservation is uncertain.

Land Use Planning Program [1]

Organized community planning activities pursuant to State enabling legislation (Section 11, Chapter 38, revised Codes of Montana) have been carried on in Big Horn County for over five years. In early 1969 the city of Hardin passed a resolution setting up a planning board, and a short time later the county commission included that county area immediately surrounding Hardin in the planning program. Accordingly, the Hardin Planning Board is officially designated the Hardin-Big Horn City-County Planning Board, and its jurisdiction extends south and east to the Crow Indian Reservation, north from the city limits two miles, and three miles west of the city limits. A comprehensive planning document was prepared for Hardin in 1972, and a capital improvements study was completed in 1974.

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[1] "Comprehensive Plan," Big Horn County Planning Board Jurisdictional Area 1974-5, prepared by Intermountain Planning Inc., Billings, Mt.

In anticipation of the prospects of massive coal development in or near Big Horn County, the county commission formed a county planning board in early 1973. The jurisdiction of this board, designated the Big Horn County Planning Board, includes the town of Lodge Grass and that portion of the county exclusive of the Hardin-Big Horn City-County Planning Board jurisdiction as well as the two Indian reservations; this is the area discussed and analyzed in this statement.

Because of the need for area-wide and intergovernmental coordination, an area planning organization was also instituted and designated the Big Horn Area Planning Organization, or Big Horn APO. The APO was joined by the city of Hardin, the town of Lodge Grass, and Big Horn County. It is intended that this APO will be the nucleus of a much larger area planning program to include the Indian reservations and thus provide a forum for discussion of common problems and coordination of their solution.

The Goals and Objectives of the Bighorn County Planning Board include:

1. Attaining the best possible living and working environment in the planning area.
2. Promoting the wise use of Big Horn County's economic resources in a manner which will co-exist with present elements of the county's economy.
3. Developing the best possible system of public facilities and utilities commensurate with county growth.

At the present time very limited progress has been made in developing this concept of integrating the Indian and non-Indian jurisdictions into a workable whole. As indicated, the town of Lodge Grass in the Little Big Horn Valley is involved in the planning process of the Big Horn County Planning Board.

To date, the planning board has not opened an office or employed a resident planner, although they have used extensive consultant services. A good deal of background information has been gained, a capital improvements study is continuing, and discussion between representatives of non-Indian and Indian interests on plan coordination has taken place.

Big Horn County, including the town of Lodge Grass, adopted a subdivision ordinance in May 1974. This ordinance prohibits a developer from recording a plat which does not conform to the State law and local ordinance. This insures that the developer goes far beyond the mere alignment of roads and location of easements but now includes the public adequate open space for light, air and recreation; provides sanitary facilities; and avoids congestion.

The Crow Tribe has not adopted a subdivision ordinance and apparently the mandatory aspects of the State law do not apply to the Crow Reservation. However, within their own jurisdictional authority, the Crow Tribe can adopt an ordinance utilizing the same self-policing principles. This relatively simple operation would provide the basic tools for developing an effective land use controls program.

The only governmental entity now having a zoning authority is Hardin, which has authority up to one mile from its corporate limits. The town of Lodge Grass is considering adoption of a similar authority. The provisions of the ordinance regulate the use of lands, the height and size of buildings, open spaces, density of population and provide other criteria for the unified development of facilities such as roadways, utilities, parks and waste disposal.

Sheridan County, Wyoming, to the south, reflects a similar situation except that the important subdivision ordinance had not been adopted. Sheridan has grown much faster than Hardin; thus its needs for planning are greater. However, its level of plan development is very similar to that of Big Horn County.

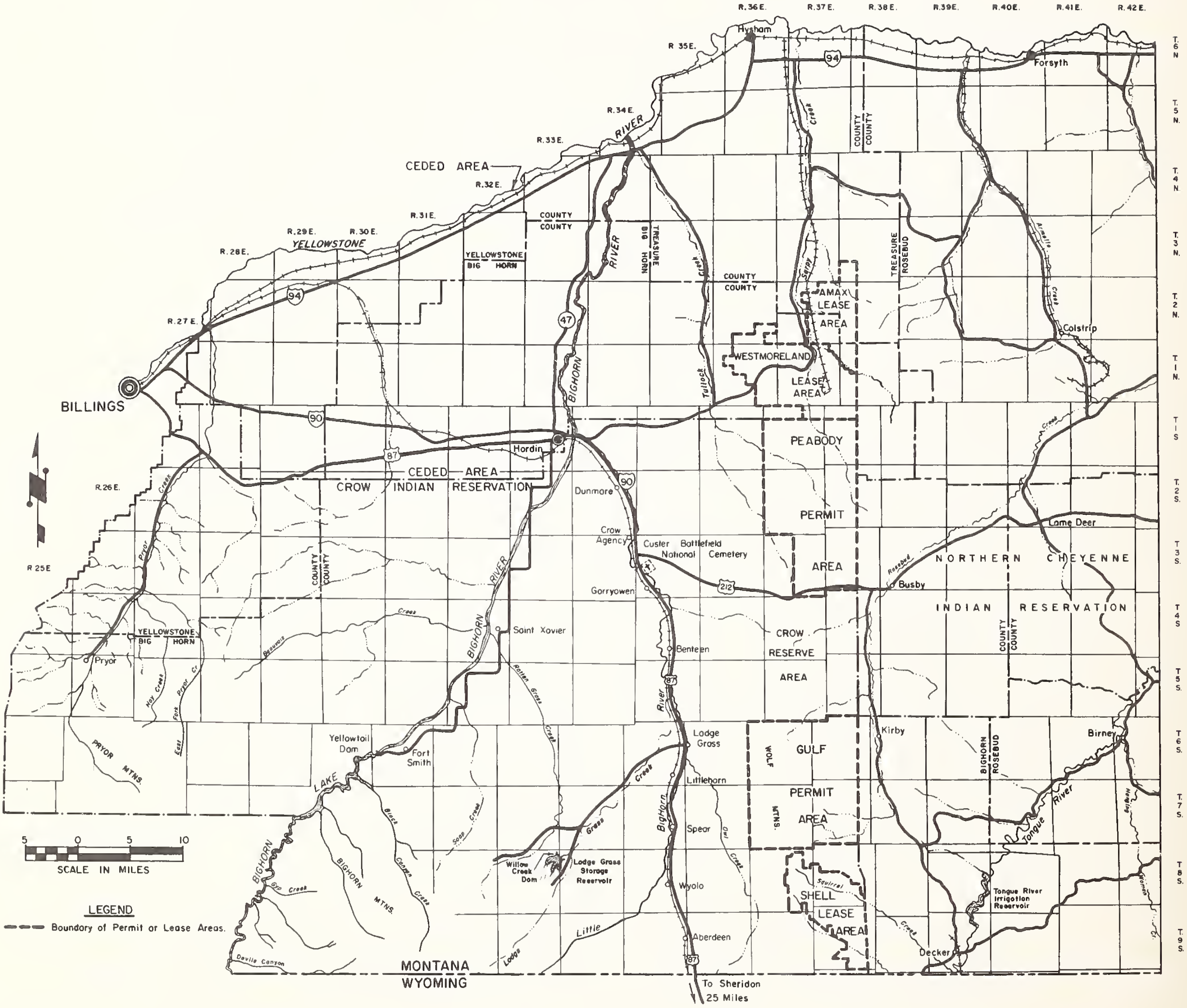
Transportation

As shown on Map 4 (page 72), there is a relatively well developed transportation system along the edge of the impacted area, although the coal bearing area itself has few allweather roads and very limited rail service.

Interstate 90 runs north and south just west of the coal area. The distance from Interstate 90 to the western boundaries of the permit and lease areas varies from 27 miles in the north to approximately four miles in the southern portion. This highway is heavily traveled as it is the principal road through the reservation and the only artery between Billings, Montana and Sheridan, Wyoming.

MAP 4

CROW RESERVATION REGION TRANSPORTATION NET



U. S. 212 is a two-lane paved highway crossing the eatern one-third of the reservation in an east-west direction. It roughly coincides with the south boundary of the Peabody Coal Company permit area and is located three to six miles from an area being considered for possible development. U. S. 212 carries most of the eastbound traffic originating on the reservation and westbound traffic entering the reservation, and thus is a fairly heavily traveled highway.

Another arterial highway, Interstate 94, is approximately 45 miles north of Crow Agency headquarters, connecting Chicago and points east with Seattle and intermediary points.

The nearest major railroad is the main line of the Burlington Northern about 47 miles north of Crow Agency headquarters. A branch line parallels the Little Bighorn River and Interstate 90 from the main line at Billings to Sheridan, Wyoming. A recently completed spur from the mainline to the Westmoreland Resources mine could be extended by secondary spurs of a few miles each into the AMAX lease and Peabody permit areas. Another rail spur from Sheridan, Wyoming terminates at the Decker Mine area, approximately six miles southeast of the Shell Oil Company's lease area.

The only direct means of transportation into the leased portion of the Ceded Area is along county roads which meander from Hardin to Hysham and Colstrip. Montana Secondary Highway No. 384 in Big Horn County is paved for 12 miles east from Hardin, after which it is gravelled and changes to Big Horn County Road Number 2. It passes through areas under lease, ending at farms to the east. At a point a few miles west of the Westmoreland mine it intersects with others leading to Hysham and Colstrip. The distances from that intersection to Hardin, Hysham, and Colstrip are about 26, 35, and 35 miles respectively. Until mine development began, the roads were used primarily by the few farmers and ranchers of the area and traffic was minimal.

Transportation routes into the eastern portion of the Crow Reservation, containing the coal mining permit areas, are mainly along gravelled or graded county roads or truck trails. These roads and trails meander from Hardin, Crow Agency, Lodge Grass, or Wyola to Busby, Kirby, or Decker and are presently used almost entirely by farmers, ranchers, or hunters so traffic is light.

Commercial air service is available in Billings, 62 miles west of Crow Agency headquarters. An airstrip capable of serving small aircraft is adjacent to Hardin.

THE PHYSICAL ENVIRONMENT

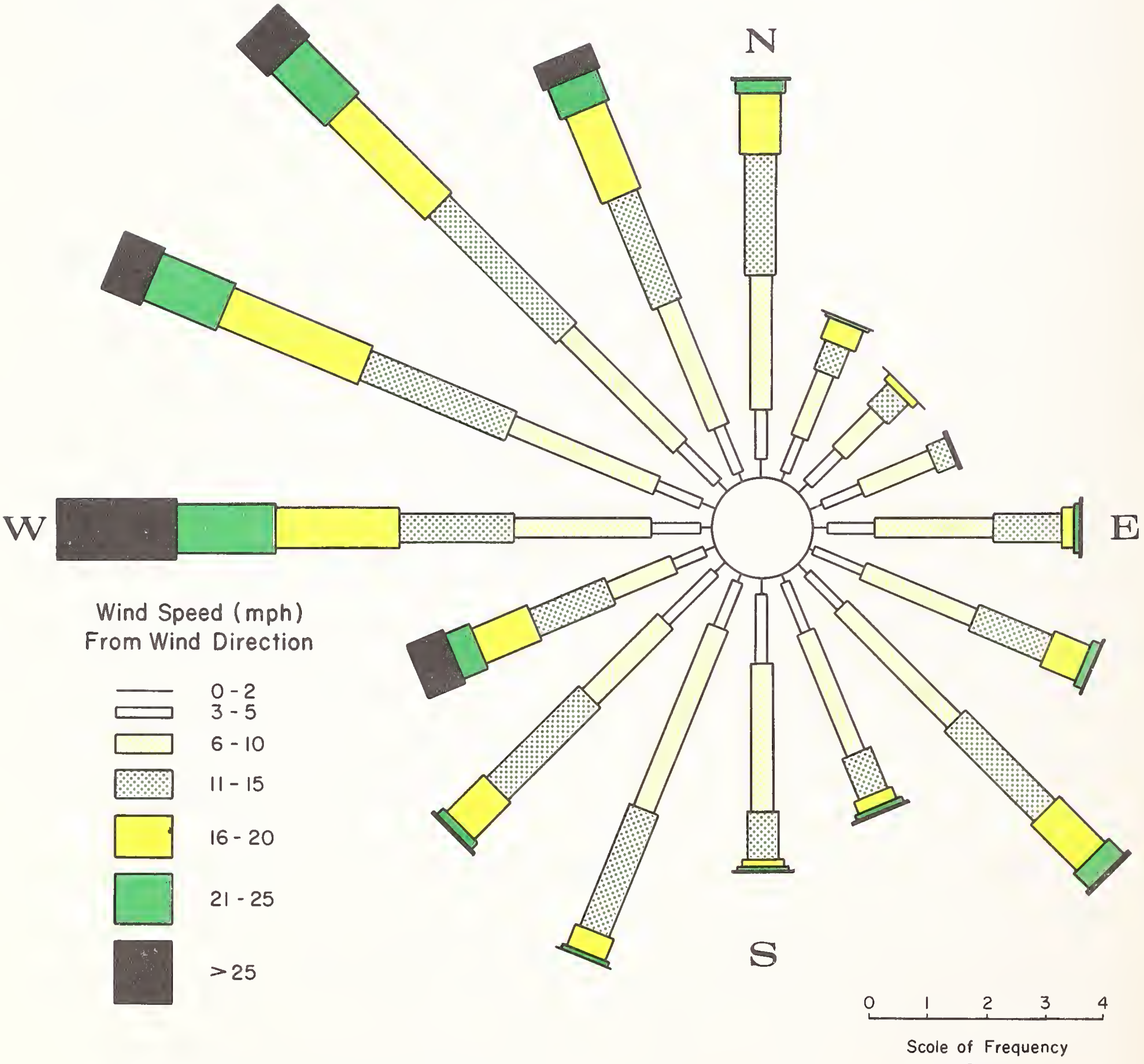
As shown on Map 4 (page 72) the coal deposits are in a band approximately two townships wide along the eastern borders of the Ceded Area and reservation from a point approximately 25 miles south of the Yellowstone River to the Wyoming border.

Climate

The Crow coal-bearing area lies in the path of one of the continent's major upper air flows. (7) As a result, pressure systems continually pass through, from the west or northwest, in an easterly direction. The pressure systems vary with the season of the year, causing a flow of cold artic air from western Canada and storms from the Pacific to dominate the winters, while in the late spring and early summer, moist, warm air from the Gulf of Mexico brings a major portion of the area's yearly precipitation. By late summer and early fall, the weather becomes hot and dry. The overall climate is considered semiarid.

At the surface, air flows are influenced both by circulation around the pressure systems and by the topography. No wind direction or velocity data are available for the area emcompassed by the Crow leases, but they have been collected by Montana State University for the town of Colstrip, some 25 miles to the east. (7) A wind-rose, illustrating direction and velocity averages at 307 feet above ground surface, is shown in Figure 8 (page 76). A summary of their data indicates that the velocity ranges from 0 to more than 25 mph with the predominant direction being from the northwest quadrant and the least predominant from the northeast.

FIGURE 8
COLSTRIP WIND ROSE



Compiled from wind data taken at Colstrip, Montana by Montana State University for the Montana Power Company. Instrument was in operation at top of 307 foot tower from November 12, 1971 – November 11, 1972.

Note: The summation of all the directions equal 100 percent.

The data submitted is not an accurate representation of air flows at the various sites on the reservation, since topographic features will affect wind direction and velocity. However, it generally illustrates the prevailing directions and velocities.

Results of weather station observations are shown in Table 11.

Table 11 Climatological Data at Selected Sites in the Region

	Hardin 1941-1970	Colstrip 1941-1970	Crow Agency	Busby	Wyola	Hysham 1961-1970
Annual precipitation - average	12.71"	15.79"	14.87"	13.97"	15.86"	15.03"
Annual precipitation - range	17.19"- 7.28"	19.84"- 10.10"	21.18"- 8.43"	16.36"- 6.88"	17.15"- 8.37"	18.43"- 10.89"
Annual snowfall - average	33.3 "	45.8 "	No record	44.5 "	60.2 "	No record
Growing season precipitation - aver.	7.83"	9.84"	7.61"	7.96"	8.62"	11.94"
Growing season days above 32° F - average	125	118	125	109	105	112
Growing season days above 28° F - average	149	143	151	132	137	129

Source: U.S. Weather Bureau, Billings, Montana

Climatological data indicate January mean minimum and maximum temperatures are 4° and 32° respectively. July mean minimums and maximums are 54° and 90°. The lowest temperature recorded in the area is below -40° F, while the highest exceeds 100° F. Annual precipitation averages 15 inches.

Air Quality

Air quality in the vicinity is normally excellent. The Montana State Air Quality Bureau sampled a rural area near Colstrip for particulate matter from April to September in 1972.(7) The results are shown below.

Table 12 Particulate Measurements in Atmosphere near Colstrip, Montana

	Number of Samples	High Value	Low Value	Geometric Mean	Arithmetic Mean
Total suspended Particulates	23	191	3.7	22	35.5
(24 hour average in µg/m^3) 1/					

1/ Micrograms per cubic meter.

The Air Quality Bureau feels the values should be even lower during winter months, meaning that the annual geometric mean will be closer to 15 µg/m^3. The EPA secondary standard for particulate matter in the United States on an annual basis is 60 µg/m^3 with 150 µg/m^3 24 hour maximum (Appendix B). Sulfur dioxide and several trace elements measured in the area were also much below the national averages or standards. However, it should be pointed out that during periods of drough, air quality does decrease drastically. Dust storms have lowered visibility to less than one mile in the area. Translated into particulate measurements, this would equal approximately 500 $\mu g/m^3$.

While Colstrip is some 25 to 30 miles from the Crow Reservation, there is no reason to believe the air would be of a less pristine quality on the Crow. At least one coal lessee has begun to monitor air quality to verify its present state.

Noise

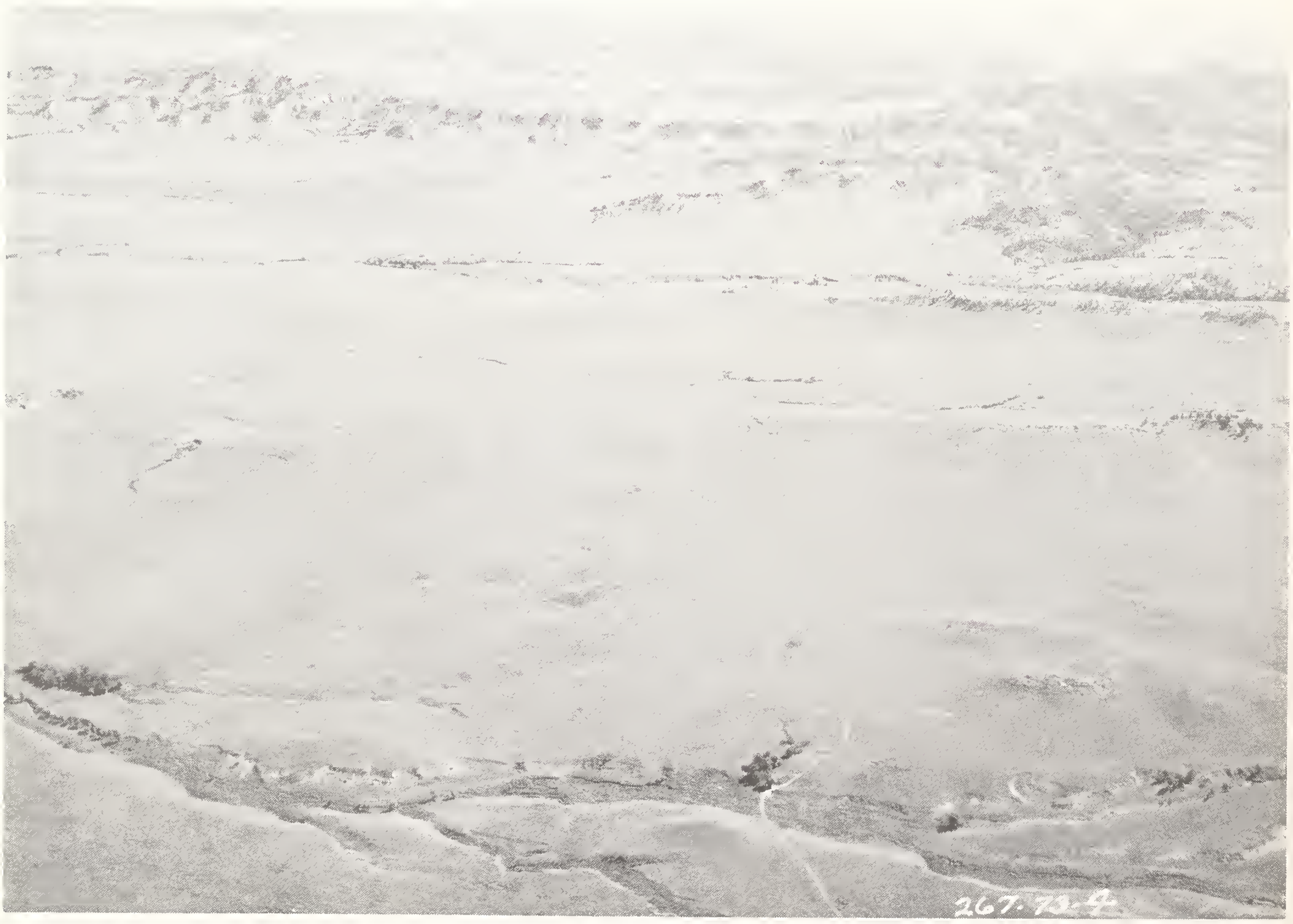
At present, the hills on the eastern side of the Crow Reservation are very quiet. While no noise measurements are available in the vicinity, similar areas have normal background sound levels below 30 decibels. The only noise that could be expected to break the stillness would be vehicular traffic, a jet airliner passing overhead, or a natural happening such as a storm or high winds.

Topography

The Crow coal resource area is characterized by rolling rangeland with ponderosa pine on the higher slopes and dryland farming on some of the high plateaus. The outstanding physical feature of the area is a long, high ridge which runs nearly the full length of the area known as the Wolf Mountains. The west slopes of the mountains rise steeply to elevations ranging from approximately 3,500 feet to over 5,200 feet. The slopes to the east are much more gradual, with large, relatively level plains a little east of the crest. These relatively level areas and the wider valleys along the creeks are utilized by the farmers and ranchers for dryland grain, alfalfa, and tame grass hay.

The norther sector of the Crow coal resource are includes the Ceded Area, the Peabody permit area, and the northern portion of the Crow reserve area. As shown in Figure 9, this sector consists of rolling rangelands peaked with frequent groves of ponderosa pine on the north- and east- facing slopes, and some farm lands on the flood plains and high benches. The elevation varies between 3,200 and 3,800 feet.

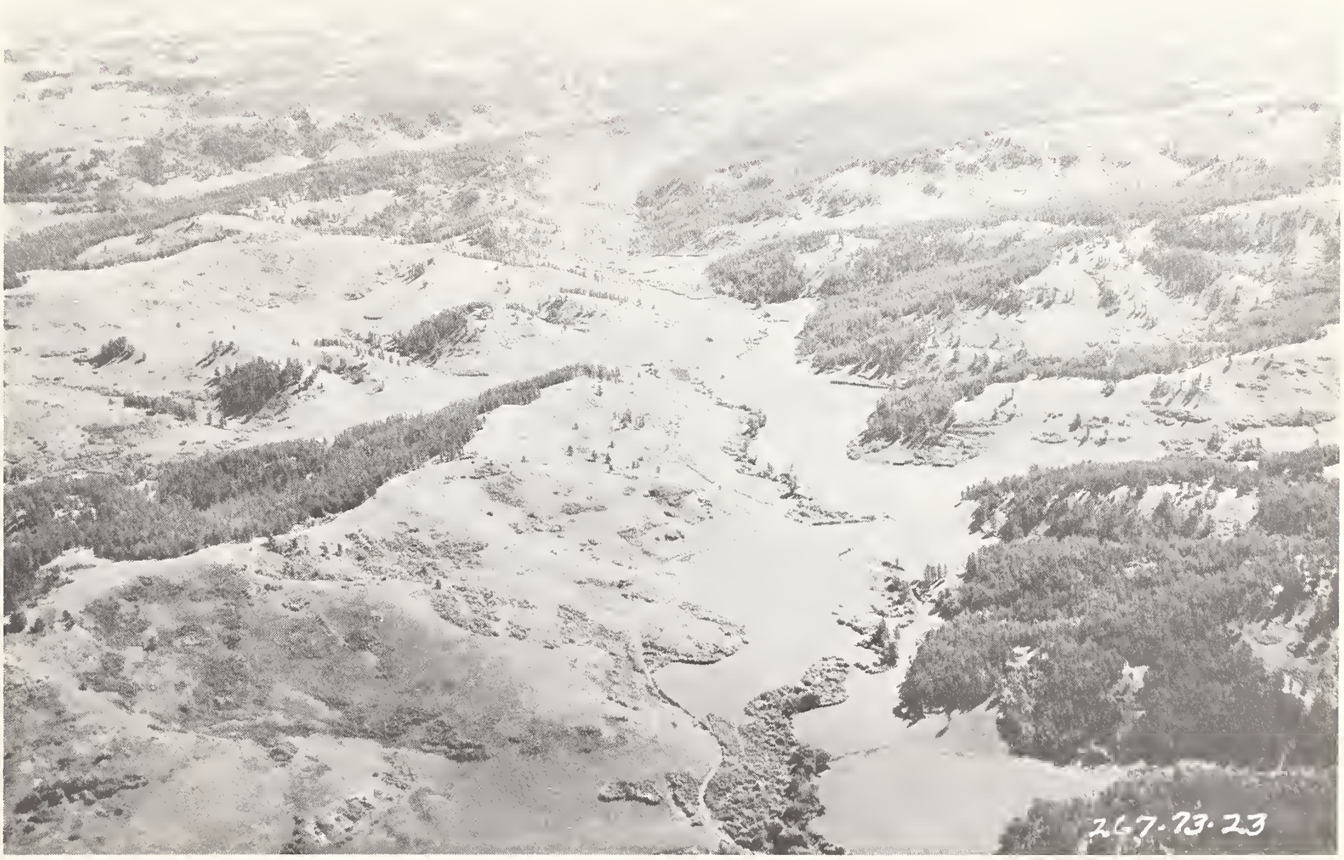
Figure 9



A Typical View of the Northern Third of the Coal Reserve Area

The central sector of the Crow coal resource area, which includes the southern half of the Crow reserve area and all of the Gulf permit area, is in the south central portion of the eastern half of the Crow Reservation. Shown in Figure 10, this sector is the heart of the Wolf Mountain range, with elevations ranging from 3,500 feet in the creek valleys to over 5,200 feet on the ridges.

Figure 10

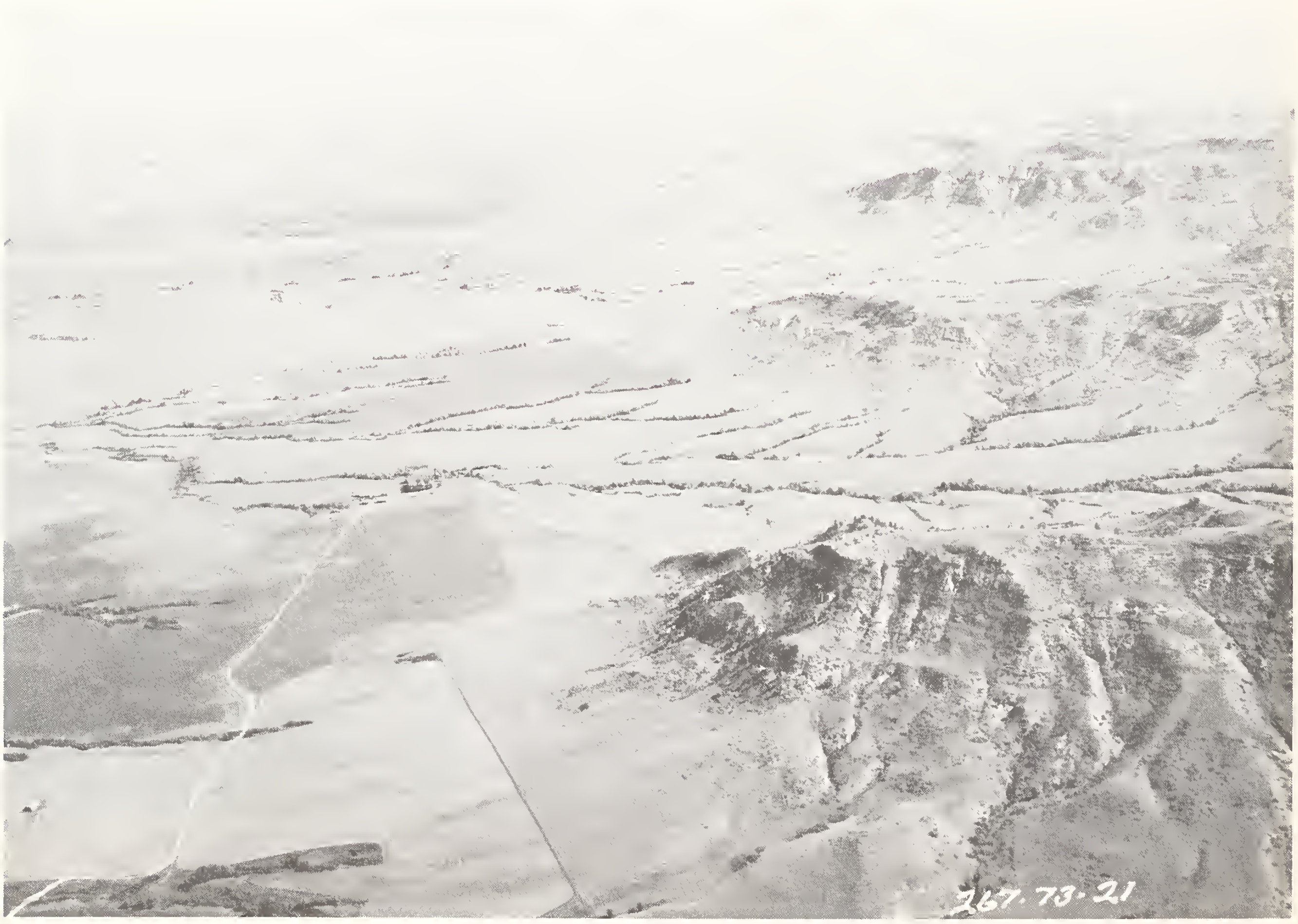


Some of the Characteristic Steep Timbered Slopes and Connecting Saddles in the Central Sector

The more mountainous terrain shown in Figure 11, has relatively steep north and south slopes covered with ponderosa pine and connected by grassy saddles. Relatively flat benches devoted to grain farming frequent the upper elevation.

This southern sector, which includes the Shell lease, is the extreme southeastern portion of the reservation. It consists of the high, more open fringes of the Wolf Mountains. This is a good game and wild fruit country with open grazing and abundant fruit bushes and trees along the drainages.

Figure 11



A Composite Example of the Terrain in the Southern Sector

The area has major drainages running to nearly all points of the compass. The main drainages flowing in an easterly direction to Rosebud Creek and then to the Yellowstone River include: Davis Creek, Thompson Creek, Corral Creek, Cache Creek, Spring Creek, Indian Creek, and the headwaters of Rosebud Creek. The south sector is drained by Squirrel Creek, Tanner Creek and Youngs Creek which flow southeasterly into the Tongue River. The west slope of the Wolf Mountains drains into the Little Bighorn River from the south fork of Reno Creek, Grey Blanket Creek, Sioux Pass Creek, East Owl Creek and Bear Creek. The area north of the Wolf Mountains and in the Ceded Area drains into the Yellowstone by way of Sarpy Creek in the northeast and Tullock and Ash Creeks in the northwest.

Although much of the topography is rugged and steep, the area is generally traversable. No extremely difficult problems have been encountered in developing roads in the area.

Esthetics

The Crow coal resource area is a natural area of rolling slopes, arable plateaus, sage flats, steep banks, rocky outcrops, pine covered slopes and ridges broken only by U. S. Highway 212 and an occasional truck trail or fence line. This is a land of endless variety, giving the impression of a timeless state which stirs the senses. The variety, beauty and isolation as expressed in Figure 9 is typical of the northern part, the transitional zone between the lower, more rolling terrain and the higher, steeper, more rustic areas which contain timbered slopes and grassy saddles. The central area is situated mostly in the Wolf Mountains and is higher, more primitive, and more scenic, as is depicted in Figure 10. The southern area is rolling rangeland cut by drainages with some sharp bluffs and little timber as shown in Figure 11.

Recreation

The area has a good potential for recreation. It is relatively undisturbed and the hills, ridges, bluffs and pine and hardwood groves would make a nice setting for such diversions as camping, picnicking, hiking, or backpacking. Deer, pronghorn antelope, and upland game birds, as well as numerous other animals and birds, could provide hunting in season, and nature study year-round.

The recreational potential is not presently heavily exploited with use being essentially limited to residents of the coal resource area and the Little Big Horn valley. Most of the land, except the Ceded Area, is in trust status, either tribally owned or allotted. Tribal resolutions in 1967 limited hunting of all game except upland birds and migratory waterfowl to tribal members or, under certain conditions, with a special permit, to non-Indians married to tribal members. A resolution, passed by the Tribal Council in October 1973 closed the reservation to all hunting and fishing by non-members. If the tribe does open hunting again, non-members must comply also with State and Federal regulations. Hunting in the Ceded Area is controlled by posting by the non-Indian ranchers.

One 120-acre tract falling within the Crow coal resource area has received partial recreational development which is managed jointly by the tribe and BIA. It is the federally owned Wolf Mountain Lookout, and although visitor use is not recorded, a yearly increase has been observed. A modest level of development is planned for this area in line with a general goal of conserving the wild character of the land.

There are many more accessible recreational areas on the Reservation that could be developed, and several sites have been investigated by the tribe and BIA for future development. The study area is generally so isolated, and so many more developed and more accessible places are available on the reservation and in southern Montana that public demand to utilize this area for recreation has been minimal up to the present time.

The majority of the surface acreage is being utilized for agricultural purposes by non-Indian farmers and ranchers under competency leases. These operators post or otherwise restrict access to much of the land. However, it is possible for visitors to view the scenery from country roads winding through the area.

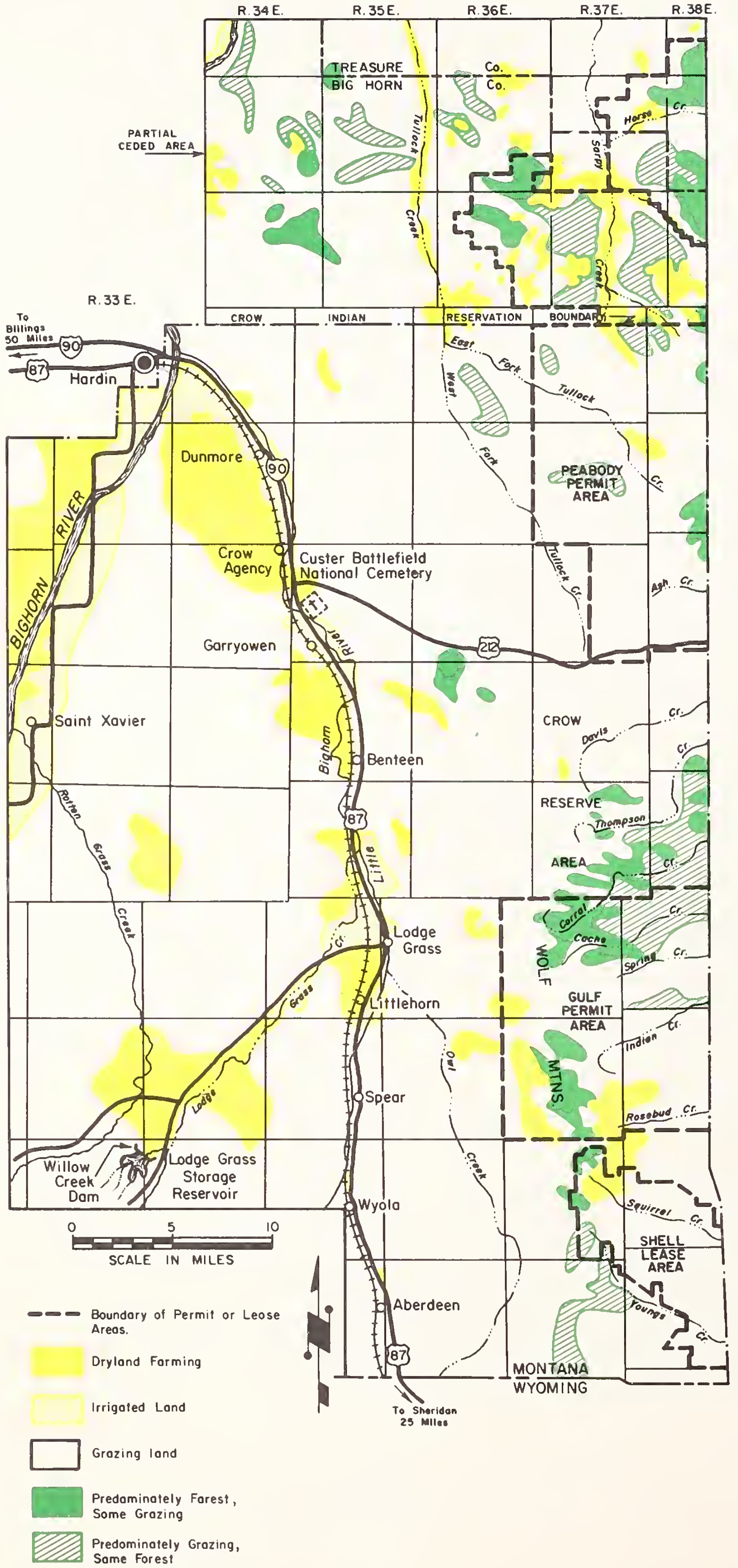
Land Use

As shown in Map 5 on the following page, land use is presently limited to agricultural and forest production. The predominant use of the coal resource area on both the reservation and the Ceded Area is livestock grazing. There is also a fair amount of merchantable timber available, although all of the timbered areas are used also for grazing, even the most heavily timbered portion.

There are extensive areas of agricultural land used for dry farming, with wheat planted on summer fallow often yielding in excess of 35 bushels per acre. The dry-crop areas, in the main, are on the high plateaus and are often interspersed with significant acreage of range land.

MAP 5

LAND USE AND VEGETATION



There are also very significant acreages of irrigated land in and adjacent to the Crow coal resource area which presently produce good yields of small grains, forage and row crops. This irrigated area, much of which is interspersed with range land, is located in the valleys of the Big Horn and Little Big Horn Rivers and tributary streams. The major communities of Lodge Grass, Crow Agency, Wyola and Hardin, as well as the major transportation routes and the commercial and residential facilities, are largely confined to these valleys. As coal development progresses, agricultural uses will compete with these other uses since both need the favorable access and terrain of these valley areas.

Since each area is slightly different from the others, their present uses merit discussion in some detail.[1/]

The southeastern sector including the Shell Oil lease is used predominantly for grazing. Several small streams which flow through the area provide a limited amount of water for irrigation. Youngs, Little Youngs, Tanner and Squirrel Creeks are spring-fed and provide enough water for at least one irrigation annually. After the first of July, these creeks do not usually have sufficient water for irrigation but are used for stock water. About 500 acres within the lease area are used for hay production, alfalfa being the chief crop. The small creeks are vital to the entire area's economy, as they provide water for the production of hay, which makes many of the ranches self-sufficient.

[1/] Approximately 2,030 acres in farmsteads, roads, ponds, barren lands, etc., are not included in the breakdown.

At 2.4 AC/AUM, the 81,700 acres of rangeland in the permit area produce about 34,000 AUM's of grazing. (9) At 1974 average rates of $5.00 per animal unit month, the estimated annual rental income was $170,000. Hay production within this lease area would gross approximately $30,000 annually, with rentals for the hayland earning $6,250. 1/ In addition, there are approximately 2,300 acres of dry farmland on the high benches in the northern portion of the southeastern sector which will earn about $86,250 annually, with $28,750 being assigned as land income.

The area within the Gulf prospecting permit lies to the north of the Shell lease within the Wolf Mountain range. There are a few large dry-farming operations on the plateaus of these mountains. Approximately 4,200 acres are currently being dry-farmed, and approximately 800 acres of alfalfa is being produced along the streams in the permit area, grossing each year approximately $157,500 and $36,000 respectively. The land portion of this gross return would be in the neighborhood of $52,500, with $10,000 for the dry cropland and the hay land. Approximately 74,300 acres of rangeland in the permit area yields 32,300 AUM's of grazing, assuming 2.3 AC/AUM and a $5.00 annual lease rate per AUM. (9) The estimated annual rental income would be $161,500.

The elevation is over 5,000 feet throughout much of the area and precipitation averages 18" to 20" or more annually, higher than in most of the surrounding area. Due to the high rainfall and productive soils, yields are considerably above the county average. Wheat yields vary all the way from the county average of about 35.0 bu/ac to 50 bu/ac. Early season freezes and snowfalls sometimes damage the crops, and

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1/ Assumptions are based on 1/3 crop share for grain, 30 bu/ac and $2.50/bushel and alfalfa land at 1.5 ton/acre and $40/ton.

sections of unsurfaced roads may delay moving the grain to market.

Indian, Spring, Cache, and Corral Creeks flow from the Wolf Mountains into Rosebud Creek and are spring-fed throughout the year. Their long season of flow and the natural shelter make the area especially desirable for cattle raising. Large acreages of alfalfa are grown downstream, along Rosebud Creek on the Northern Cheyenne Reservation. Interruption of flow in these creeks would affect hay production over a wide area.

The Gulf area contains some of the better timber stands in the Crow coal resource area.

The Crow reserve lies between the Gulf permit on the south and the Peabody permit on the north. Situated mostly in the central mountainous sector, it includes apporximately 1,800 acres of dry-farm land and 1,700 acres of hay land grossing approximately $67,500 and $102,000 respectively. The portion of this gross assigned to land is $22,500 for dryland and $21,250 for the hay land. The approximately 76,800 acres of rangeland would produce about 29,500 AUM's of grazing, assuming 2.6 AC/AUM and a rental rate of $5.00 per AUM, while the estimated annual rental income would be $147,500. In addition, this tribal reserve contains good timber stands.

In the northern sector the Peabody permit, approximately 15 miles north of the Gulf permit, is used almost exclusively for grazing and produces approximately 26,200 AUM's on approximately 83,900 acres of rangeland at an assumed 3.2 AC/AUM.(9) At $5.00 annual permit rate per animal unit month, the estimated annual rental income would be

$131,000. Approximately 1,300 acres are currently being farmed, plus about 950 acres of alfalfa, which together would gross about $105,750 and return $28,125 as the land's share of the gross income. The area receives less rainfall and is less productive than the rest of the Wolf Mountain area.

Presently, grazing is the predominant use, with approximately 317,584 acres of on-reservation rangeland being used. Approximately 10,500 acres are dry-farmed, and hay is raised on about 3,200 more. There are approximately 122,000 animal unit months of grazing available in the four on-reservation tracts.

An additional land use of the area is its contribution to the watershed. The whole Crow coal resource area is a recharge area for numerous creeks, streams, and springs emanating in the Wolf Mountains and for the areas lying below in the drainage basin.

In the Crow Ceded Area, just north of the reservation and adjoining the Peabody permit, mineral leases issued cover a total of 45,113 acres. The predominant use is cattle grazing, with 42,529 acres of rangeland having a carrying capacity of 13,290 animal unit months, assuming 3.2 acres per AUM. The estimated lease value, based on reservation figures, is $66,450 annually. Approximately 2,582 acres are being farmed, with alfalfa, hay and small grains as the principal crops. Using the same acreage value assumed on the other areas, leasing the dryland farms would bring in about $32,275 as the land's share of the gross produced.

The farm and ranch operators in the Ceded Area are all non-Indians utilizing land owned by themselves or leased from other non-Indian owners.

Land Ownership

On the reservation portion of Crow coal resource area, virtually all of the operators are non-Indians who own part of their land and in most cases lease part of their ranch units from individual Indian allottees.

Altogether the Crow coal resource are includes approximately 376,397[1] acres. The land ownership in this area is shown in Table 13.

Table 13

Crow Coal Resources Area
Land and Mineral Ownership[2]

	Mineral			Surface[3]		
	Fee	Tribal	Allotted	Fee	Tribal	Allotted
On Reservation						
Acres 331,284	18,670	304,522	8,092	132,807	9,748	188,609
Percent	5.6%	91.9%	2.5%	40.0%	3.0%	57.0%
Ceded Area						
Acres 45,113	0	45,113	0	43,273	1,840	0
Percent	0	100%	0	95.9%	4.1%	0

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[1] Total sale acres offered. Some tracts did not receive bids and were not permitted, although they contain coal reserves.

[2] Fee mineral ownership is included; permits issued do not include the right to lease.

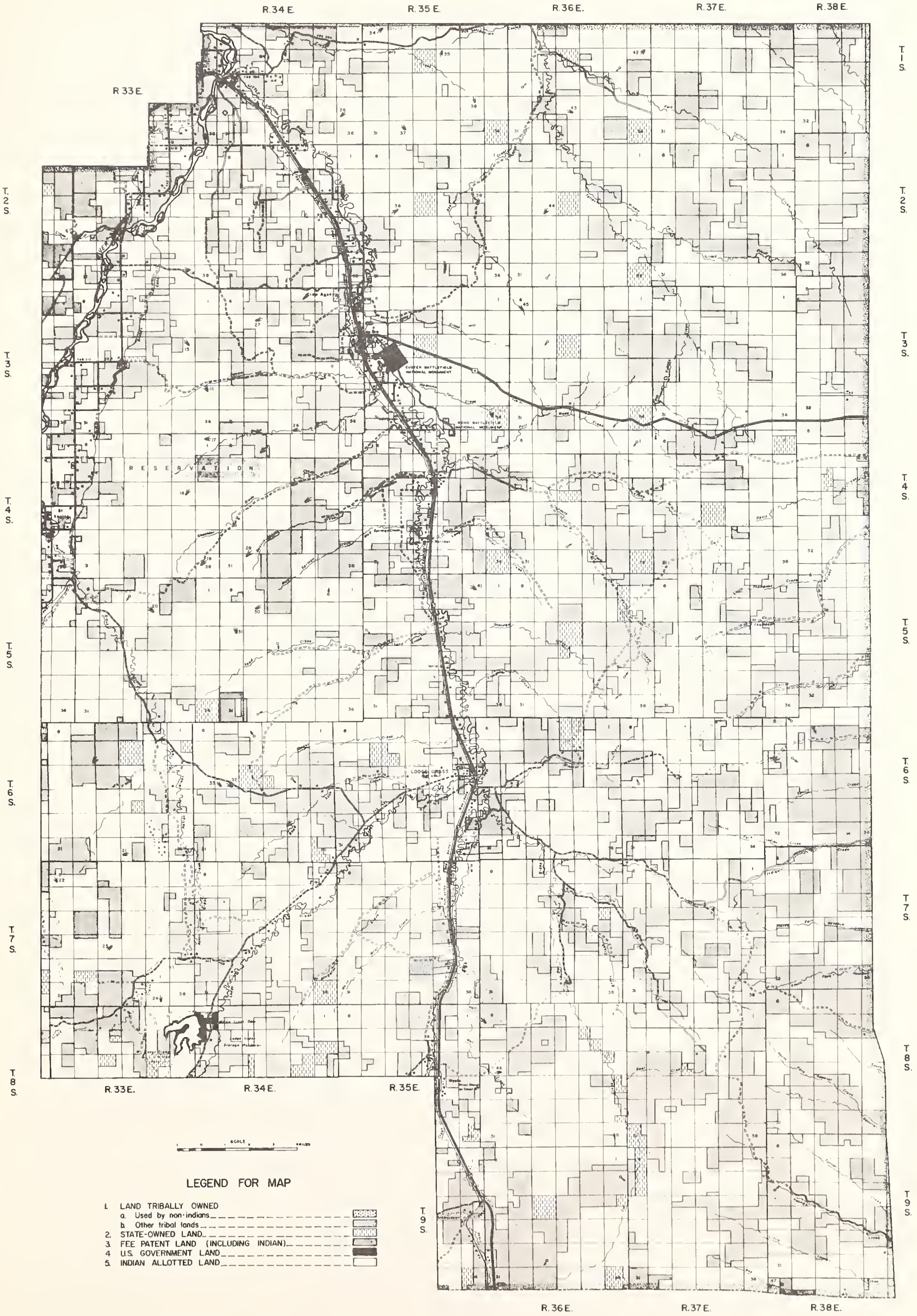
[3] Totals do not include 120 acres of Government-owned land.

As shown in Table 13, the tribe owns nearly 92 percent of the minerals on the reservation portion of the coal resources area and 100 percent in the Ceded Area portion. On the other hand, it owns only three percent of the surface on the reservation portion and four percent in the Ceded Area portion. Of surface ownership, 40 percent of the land on the reservation portion is in fee status, compared to 96 percent in the Ceded Area portion. Allotted land constitutes 57 percent on the reservation portion and none in the Ceded Area portion.

The pattern of surface ownership on the reservation is shown in Map 6. The distribution of surface ownership throughout the coal resource area appears to be relatively uniform, with no extremely large contiguous blocks in either fee or Indian ownership. This same uniformity exists in the Little Bighorn Valley, where the major residential and commercial facilities exists along with the major transportation and communications channels.

MAP 6

LAND OWNERSHIP DISTRIBUTION CROW RESERVATION - EASTERN PORTION



Timber

The forest lands of Wolf Mountains contain some pure stands of ponderosa pine. Though the species composition is uniform, there are great variations in timber age and stand density. It is the Crow Reservation's primary manageable commercial forest area. The Wolf Mountains contain about 27,500 acres of commercial forest land, of which 14,400 acres are owned by Indians. Small acreages of merchantable timber on the Ceded Area are controlled by the non-Indian surface owners.

The present system of harvest from Indian lands produces approximately 15 to 20 man-years per year of employment. Barring natural disasters such as fire and insect epidemics, the timber could provide the local economy with a continuous supply of timber at about 2.5 million board feet annual cut. With technological advances in logging and milling and greater emphasis placed on forest development activities, such as old growth harvest, thinning and planting, the forest growth will increase over the next several decades.

Timber demands and the high market values of lumber in the 1971-73 period have caused regional sawmills to become interested in purchasing Wolf Mountain timber. At mid-1973 prices, the 3 million board feet annual cut on the Crow Reservation, including the western portion of the Crow Reservation, can generate approximately $150,000 yearly to the landowners. The Wolf Mountains would account for approximately 75-80 percent of this volume. The volume and value actually harvested is subject to wide fluctuation as the lumber market varies.

Under the present selective cutting system, approximately 50 percent of a stand, an average of 3,000 board feet per acre, is left as a reserve stand. Merchantable reserve trees are generally spaced at 15- to 20-foot intervals supplemented by smaller timber to allow sufficient space to stimulate accelerated tree growth. Utilizing this system of harvest, approximately $150.00 per acre at mid-1973 prices are generated for the timber owners on a 20- to 30-year harvest cycle. The quantity of timber within the area on which strip mining is proposed is not as clearly defined as is the quantity of available grazingland. Most of the forested area, however, is in the rougher, higher terrain.

Soils

The portions of the coal resource area within the reservation were subjected to a soil and range inventory from 1964 to 1970 by the Missouri River Basin Investigations Project (MRBI), the predecessor to the Planning Support Group (9). The portions off the reservation were soil surveyed by the Soil Conservation Service (SCS), and the Soil Survey of Treasure County (10a) has been published. The Soil Survey of the Big Horn County Area (10) is in preparation, but a draft copy is available for consultation.

Map 7 on the following page shows the soil associations and near Crow coal resource area. A soil association consists of two or more soil series which occur together with some degree of regularity and are individually large enough to be mapped separately. Each soil association is named for the two or three principal member series. The associations lying within the coal resource area are numbers 8, 9, 11, 12, 13, 14, and 16. The discussion in Appendix D1 describes the principal characteristics

MAP 7

SOIL ASSOCIATIONS
CROW COAL RESOURCE AREA

LEGEND
GENERAL SOIL MAP
BIG HORN COUNTY AREA, MONTANA

SOILS OF THE STREAM TERRACES AND ALLUVIAL FANS

1	Kyle-Lohmiller-Haverson association: deep, nearly level to steep, well drained soils on flood plains, terraces, fans and foot slopes.
2	Korchea-Farnuf-Savage association: deep, nearly level to steep, well drained soils on fans, foot slopes, flood plains and terraces.

SOILS OF HIGH GRAVEL TERRACES AND FANS

3	Judith-Danvers-Windham association: moderately deep and deep, level and gently undulating to very steep, well drained soils on fans, terraces and benches.
4	Keiser-Hydro-Gilt Edge association: deep, nearly level to sloping and gently undulating to hilly, well drained soils on terraces, fans and benches.
5	Spearfish-Pultney-Stormitt association: deep, moderately deep, and shallow, undulating to very steep, well drained soils on fans, benches and sedimentary plains.
6	Wayden-Xavier-Belfield association: deep and shallow, nearly level to sloping and gently undulating to very steep, well drained soils on fans, terraces, foot slopes, benches and sedimentary plains.
7	Beauvais association: deep, gently undulating to rolling, well drained soils on terraces, fans, foot slopes and loess covered hills.

SOILS OF SANDSTONE HILLS

8	Nelson-Alice association: deep and moderately deep, sloping and moderately steep and undulating and rolling, well drained soils on foot slopes, fans, valley bottoms and sedimentary plains.
9	Dast-Vebar-Parshall association: deep and moderately deep, rolling to very steep, well drained soils on foot slopes, fans, valley bottoms and sedimentary plains.

SOILS OF DISSECTED SHALE HILLS

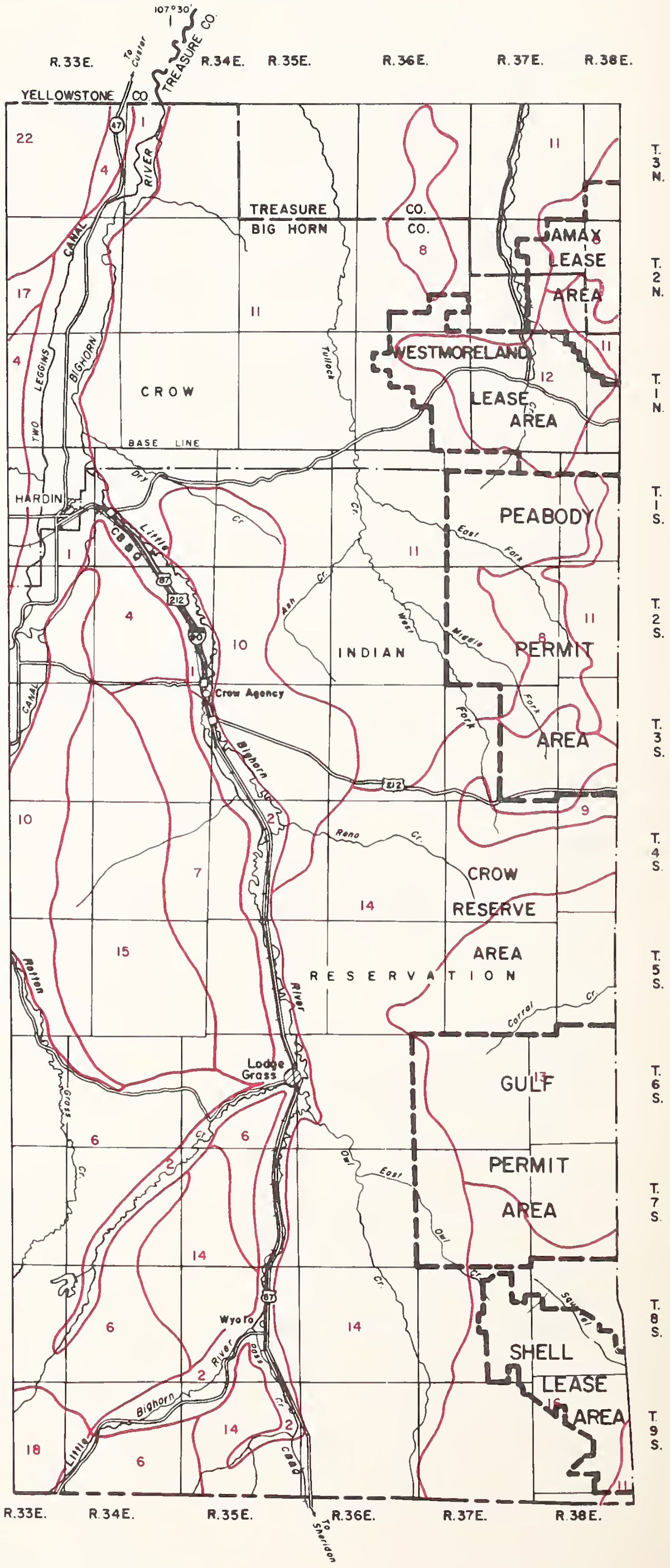
10	Pierre-Lismas-Kyle association: shallow, moderately deep and deep, nearly level to moderately steep and gently undulating to very steep, well drained soils on fans, foot slopes, terraces and sedimentary plains.
11	Thedalund-Midway association: moderately deep and shallow, undulating to very steep, well drained soils on sedimentary plains.
12	Wibaux-Thedalund-Spearman association: moderately deep and shallow, undulating to very steep, well to excessively drained soils on sedimentary plains.
13	Ringling-Searing-Arnegard association: deep, moderately deep and shallow, gently sloping and undulating to very steep, well drained soils on fans, foot slopes and sedimentary plains.
14	Doney-Reeder-Wayden association: moderately deep and shallow, gently undulating to very steep, well drained soils on sedimentary plains.
15	Midway-Nunn association: deep and shallow, nearly level to sloping, and undulating to hilly, well drained soils on terraces, fans, foot slopes and sedimentary plains.
16	Wayden-Regent-shale outcrop association: moderately deep and shallow, gently undulating to very steep, well drained soils on sedimentary plains.
17	Midway association: shallow, undulating to hilly, well drained soils on sedimentary plains.

SOILS OF INTERMIXED DISSECTED SHALE AND SANDSTONE HILLS

18	Abac-Peritsa association: moderately deep and shallow, undulating to very steep, well drained soils on sedimentary plains.
19	Absarokee-Maginnis association: moderately deep and shallow, gently undulating to very steep, well drained soils on sedimentary plains.
20	Absarokee association: moderately deep, gently undulating to hilly, well drained soils on sedimentary plains.
21	Wayden-Castner association: shallow, undulating to very steep, well drained soils on sedimentary plains.
22	Thedalund-Travessilla association: moderately deep and shallow, undulating to very steep, well drained soils on sedimentary plains.

SOILS OF THE MOUNTAINS

23	Duncom-Tarrete-Mayflower association: moderately deep and shallow, rolling and hilly, well drained soils of the mountains.
24	Lap-Armington-Reeder association: moderately deep and shallow, gently undulating to very steep, well drained soils of the mountains.



5 0 5 10 MILES
SCALE 1:500,000

Source : Soil Conservation Service

Table 14

Characteristics of Some Very Extensive Soils of the Crow Coal Resource Area, Their Productivity, and Their Suitability as Topsoiling Material in Reclaiming Strip-mined Land 1/

Soil Series and Texture 2/	Range Slope (%)	Depth	Parent Material	Permeability	Water holding capacity (ins.)	Elevation (feet)	Ann. ppt. (ins.)	Range Site(s) 3/	Use 4/	Rating for Topsoiling
Arnegard SiL, L	2-35	deep, 60"+	alluvium	moderate	8-10	3,500-4,800	14-17	Si, Sb	dry & irrig. crop	excellent
Belfield SiL	0-8	deep, 60"+	alluvium loess	mod. slow	9-11	3,400-4,500	14-17	Si	irrig. & dry crop	fair
Dast SL	8-90	mod. deep, 30-40"	sandstone	mod. rapid	2-4	3,400-4,200	14-16	Sy, TSy, Forest	-	fair
Doney L SiCL	4-95	mod. deep, 30"	shale, siltstone, sandstone	moderate	3-4	3,500-5,000	14-18	Si, Tsi	-	poor
Ft. Collins L	0-15	deep, 60"+	alluvium	moderate	9-11	2,850-3,400	12-14	Si	dry & irrig. crop	excellent
Grail CL, SiC	0-35	deep, 60"+	alluvium	mod. slow	8-10	3,500-5,000	14-17	Cy, Sb	dry & irrig. crop	very good
Heldt SiCL, SiC	0-15	deep, 60"+	alluvium	slow		2,800-3,500	12-14	Cy	dry & irrig. crop	good
Hydro L, SiL, SiCL	0-8	deep, 60"+	alluvium	slow	9-11	3,000-3,800	13-15	Si	dry & irrig. crop	fair
Kim L	4-15	deep, 60"+	limy alluvium	moderate		2,900-3,500	13-14	Si	dry crop	good to very good
Korchea L, SiL, SiCL	0-35	deep, 60"+	strat. limy alluvium	moderate	10-12	3,300-4,300	14-17	Sb	irrig. & dry crop	very good
Lismas C, gravelly C	4-35	shallow, 10-20"	shale	slow to very slow	2-3	3,000-3,800	12-14	SwC	-	unsuitable
Midway SiCL	2-35	shallow, 15"	shale	slow	1-3	3,000-4,000	12-14	Cy TCy	-	poor

Morton SiL	4-8	mod. deep, 36"	siltstone	mod- erate	6-7	4,500- 5,200	16- 18	Si	dry crop	good
Nelson FSL	4-15	mod. deep, 30"	sandstone	mod. rapid	3-5	3,000- 3.800	13- 14	Sy	-	good
Nunn SiCL	0-15	deep, 60"+	alluvium	slow	8-10	3,300- 3,700	14- 15	Cy	dry crop	good
Pierre C	2-35	mod. deep, 20-40"	shale	very slow	3-5	3,000- 3,800	13- 14	Cy	dry crop	poor
Ringling	8-95	shallow, 15"	burned shale	rapid	1-2	3,400- 5,000	14- 17	TSi, TB	-	poor
Searing L	4-35	mod. deep, 30"	burned shale	mod- erate	4-5	3,500- 5,000	15- 17	Si, Forest	dry crop	good
Shaak SiCL, CL	0-15	deep, 60"	alluvium, shale	slow	6-8	3,500- 5,000	14- 17	Si	dry & irrig. crop	good
Thedalund L	4-90	mod. deep, 28"	siltstone	mod- erate	4-5	2,800- 3,800	12- 14	Si, TSi	-	poor
Wages L	0-8	deep, 60"+	limy alluvium	mod- erate	8-10	3,000- 3,600	13- 14	Si	irrig. & dry crop	excellent
Wayden SiCL	4-55	shallow, 20"	shale	slow	3-4	3,600- 4,600	14- 17	Cy, TCy	-	poor

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1/ For other common soils and a few additional soil characteristics, see Appendix D-4.

2/ Soil series are not exactly synonymous with soil mapping units which may consist of one or more series. A series may be in one or more soil mapping units.

3/ For definitions of the range sites see Appendix E-2. For their correlation with the plant community types, see page of the vegetation discussion. Range sites serve as one measure of soil productivity.

4/ Each soil is used also for grazing and to some extent as wildlife habitat. The permissible use of a soil is another measure of its productivity.

Sources: Soil Survey, Big Horn County Area (10); Soil and Range Resource Inventory. East of Little Bighorn River (9).

of each association or the member soil series, as well as the usefulness of each soil in reclaiming strip-mined land.

Soils which have similar profiles are called series. Soils within a series can differ in texture in the surface layer or horizon, slope, stoniness or other characteristics which affect man's use of the soil. On the basis of these differences the series are divided into phases, which for practical purposes are the same as mapping units. Lists of the soil mapping units are in Appendix D2 and D3.

Table 14 (pages 97-98) is useful for comparing several important characteristics of the most extensive soil series in the Crow coal resource area. Apendix D4 is an expansion of this table to include some additional characteristics and all the common soil series of the coal resource area.

The soils in the immediate area of the proposed mining sites are shallow to moderately deep with the exception of the valley soils, which are deep and fertile.

Vegetation

The Crow coal resource area supports at least thirteen types of plant communities. In the recent soil and range inventory of the area the vegetation types were mapped as 14 range sites and two ponderosa pine forest types. In either system of classification, the plant species composition depends on the following:

(1) Three precipitation zones: 10 to 14 inches, 15 to 19 inches, and 20 to 24 inches of annual precipitation. The least precipitation is in the Ceded Area and the northern two tiers of townships in the Crow Reservation portion. The greatest precipitation is in the highest part of the Wolf Mountains.

(2) Altitude: In general, the least annual precipitation occurs on the lower areas and the greatest annual precipitation occurs at the higher elevations.

(3) Various soil characteristics such as depth, texture, slope, gradient, and moisture relationships.

(4) Direction of slope, sometimes called the aspect. South- and southwest-facing slopes tend to have the most xeric (dry site) vegetation. North- and northeast-facing slopes tend to have the more mesic (moist site) vegetation.

The combination of these four characteristics determines the composition of the individual plant community. Refer to Appendix E-1 for a description of each community and its usual habitat and to Appendix E-2 for a description of each range site. The list of plants is in Appendix F.

Map 5 on page 86 shows in a very general way the location of irrigated land, dry crop areas, grazing land, and forested land.

Relationships of the Plant Community Types to Range Sites - The 14 range sites mapped on the east side of the Crow Reservation are Wet Land (WL), Subirrigated (Sb), Overflow (Ov), Sands (Sa), Sandy (Sy), Silty (Si), Clayey (Cy), Thin Sandy (TSy), Thin Silty (TSi), Thin Clayey (TCy), Shallow Clay (SwC), Panspots (Ps), Thin Breaks (TB), and Shale (Sh).

Plant community types 5, 6, 7, 8, and 9 listed in Appendix E-1 may each include areas of the Overflow, Sands, Sandy, Silty, Clayey, Thin Sandy, Thin Silty, Thin Clayey, Panspots, and Thin Breaks range sites.

Most of the Sandy range sites and all of the Sands sites are in the Peabody tracts and Ceded Area. The following plant species are restricted largely to these two range sites or to other somewhat excessively drained areas: sand bluestem, prairie sandreed, mat sandbur, Indian ricegrass, sand dropseed, bee spiderflower, small soapweed (yucca), Bessey cherry, and skunkbush sumac.

Plant community types 10 and 11 may each include a high proportion of the Subirrigated range site as well as smaller amounts of Silty, Clayey, Thin Silty, and Thin Clayey range sites. Plant community type 12 is identical with the Wet Land range site. The Shallow Clay and Shale range sites are minor constituents in the area considered for strip mining. Their vegetation is a grassland type.

Plant Succession Under Present Land Use - It appears that the native vegetation is in a fairly stable condition approximating the climax state, but occasional species such as annual grasses, dandelion, and other invader plants may make up a significant part of the plant cover. If mining were not carried out, there should be no deterioration in the vegetative composition unless overgrazing is permitted.

Formerly cropped areas that have been abandoned to crop use have returned to a grassland vegetation but with a much higher percentage of cheatgrass brome and certain forbs. Presumably, the vegetation will eventually approximate a climax state, but certain desirable species such as bluebunch wheatgrass are extremely slow in reinvading a former habitat.

Fish and Wildlife

There is currently no documented information available on wildlife population numbers on the Crow coal resource area. A partial list of wildlife species that inhabit the section of the reservation east of the Little Bighorn River was developed by a BIA team making a resource inventory report during the period 1964-1970. (9) The findings of this team are listed in Appendix G. To this list, a few more species have been added based on personal observations. An extended list of wildlife species is included in Appendix D, pages 227-231 of the Westmoreland Resources Mining Proposal, FES 74-8 (1).

The following information on the reservation portion of the coal resource area is based on personal observation and conversation with Mr. Robert Playfair, Range Conservationist, Crow Agency, BIA.

Big Game - Mule deer are the most common species of big game in the area and are found throughout the higher elevations. Their population is roughly estimated to be several hundred animals in the permit and lease areas. Whitetail deer are less common and frequent the lower elevations, mainly along the creek bottoms where cover is dense. Elk are reported to occupy some of the area under the Shell and Gulf lease and permit agreements; however, their numbers are few, estimated at around 25 animals. Pronghorn antelope are seen occasionally in the lease areas. The climatic and range conditions are adequate for all big game species, with the exception of the antelope, to occupy the area on a year-round basis. The range condition appears to be good for all seasons except winter, where the indication is that the range is overused and in only fair condition.

Game Birds - Sharptail grouse are very common in the grassland-brush habitat that makes up much of the area. Other game birds (ruffed grouse, sage grouse, Hungarian partridge, and ring-necked pheasants) are relatively few in numbers. Waterfowl use is also relatively insignificant due to the small amount of available habitat.

Other Birds and Animals - A wide variety of songbirds utilize the area during the spring, summer and fall seasons. Some of the species, being nonmigratory, are year-round residents. Rodents of many forms are common on the area, the most important species being the prairie dog because of its relationship as prey for the endangered black-footed ferret. Most of the prairie dog towns are in the original Shell permit area and at least two are inside the lease area. The presence of black-footed ferrets in the area has not been confirmed; however, their secretive nature, coupled with the fact that only a few could occupy the area, may have caused them to go unnoticed. The coyote is the primary predator in the area, but bobcats and mountain lions are reported to be present.

Raptorial birds are common throughout the area. American kestrels and red-tailed hawks are the most abundant and both species are presumed to nest on the reservation. Both bald and golden eagles occupy the area just east of the Crow Reservation. Based on this fact, it is logical to assume that both nest in the coal lease areas of the Crow Reservation. Prairie falcons are uncommon in the area although nesting of this species probably does occur here.

No endangered species have been reported on the Crow Coal resource area.

Fish - Fishery habitat in the proposed coal development areas consists of small mountain streams and stock ponds. Nearly all the streams are intermittent or occasionally experience extremely low flows. Stock ponds are small, generally less than five acres, and most of them fluctuate considerably. None of the streams surveyed during 1973 contained naturally reproducing populations of trout. Most contained several species of nongame fish. There are no known rare or endangered fish species in any of the drainages in or near the coal development areas.

Some of the deeper stock ponds contain stocked populations of brook or rainbow trout. Where these are on a live stream, the trout extend up- and downstream from the pond for varied distances determined by barriers or suitable habitat.

Most of the streams surveyed contained white sucker, lake chub, and longnose dace. For a complete inventory of fish species known to occur in the area, refer to Appendix H. Older residents of the area report some of the streams previously contained good populations of brook trout. Low summer flows combined with winter icing and a general lack of deep holes, such as those provided by beaver ponds, have contributed to a stream environment which is unsuitable for trout.

Although the streams within the proposed coal development area contain few game fish, they are tributary to large streams that do support fishable populations. Streams in the southeastern part of the Wolf Mountains are tributary to the Tongue River which contains rainbow trout, brown trout, smallmouth bass, rock bass, walleye, sauger, northern pike and channel catfish. The State lists this section of the Tongue River as a Class 4 stream -- limited in fishing value to smaller districts in the State, such as a county.

Streams along the eastern part of the Wolf Mountains drain into Rosebud Creek which supports a put-and-take rainbow trout fishery on the adjacent Northern Cheyenne Indian Reservation.

Along the western side of the Wolf Mountains, streams drain into the Little Bighorn River which contains rainbow, cutthroat and brown trout. The State lists this section of the river down to Lodge Grass as a Class 3 stream -- one having fishing value to large districts of the State -- and from Lodge Grass downstream to the Bighorn River as a Class 4 stream.

Streams in the mining permit areas of the northeastern part of the reservation drain into Tullock and Sarpy Creeks. The latter drainages contain no game fish except in the extreme lower reaches where they join the Yellowstone River. Channel catfish are reportedly caught here during times when flows are adequate.

Geology

Rocks exposed on the Crow coal resource area range in age from Precambrian to Recent (Holocene). The table of formations (Appendix 1), is modified from earlier work in adjacent areas done by Renick(12), Thom and others, (13) Magill and others, (14) Hamilton, (15) and Hopkins. (16)

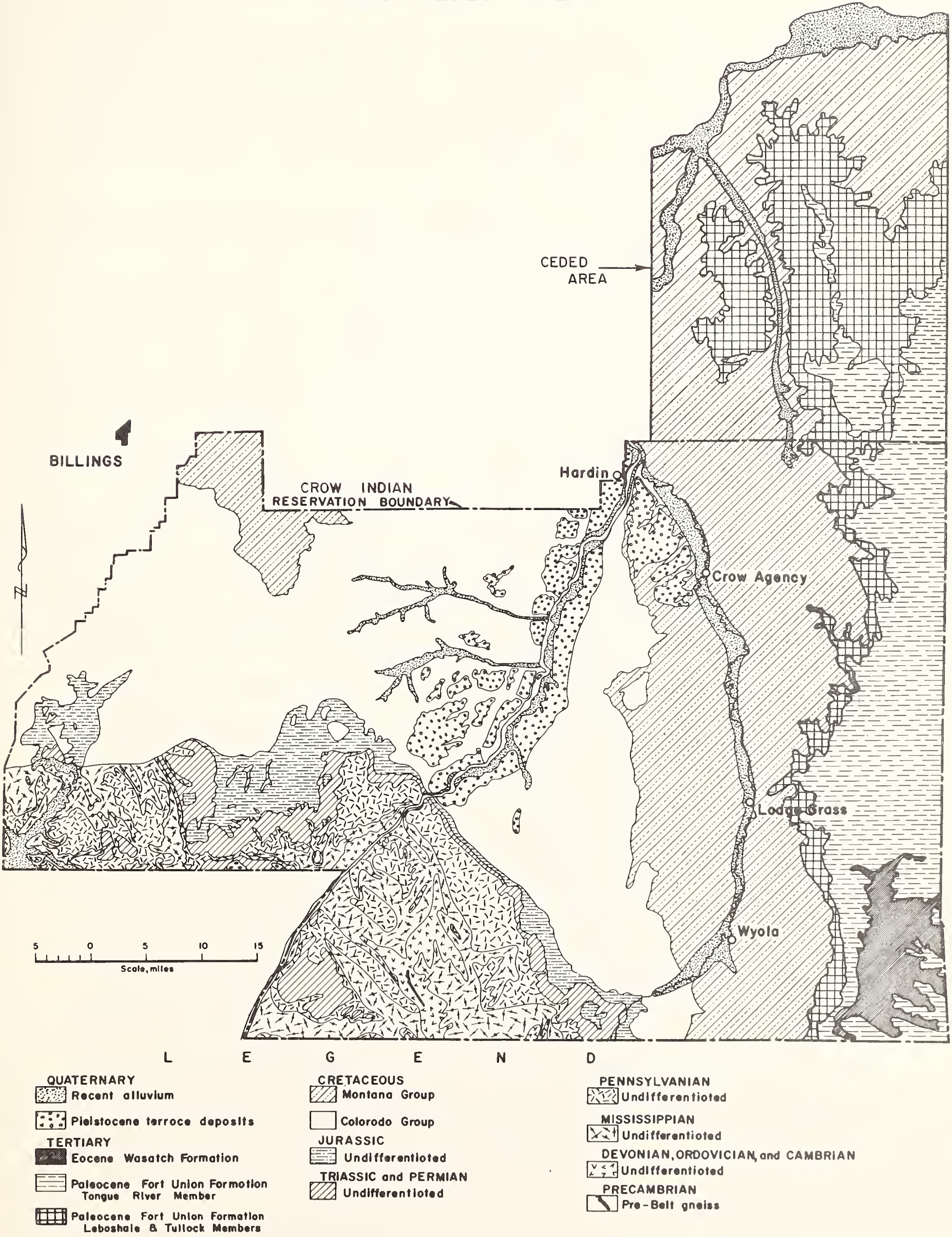
Some formational names used by earlier authors have been revised for this report; others have been retained even though they have been modified or superseded on the basis of later studies. Thicknesses indicated are approximations from other reports. The maximum and minimum figures may be valid for places several miles or tens of miles from the Crow coal resource area.

The Bighorn and Pryor Mountains are the major topographic features on the Crow Reservation. The uplift that produced these mountains is part of a great northwest-striking anticlinal fold that was formed in early Tertiary time. Sedimentary formations dip away from the center of the uplift to the east, north, and west. Dips range from 15° to 90°. A narrow belt of foothills or hogbacks, in which the beds dip from 45° to 90°, surrounds the mountain mass. The formations are nearly flat, lying beneath the plains which form the greater part of the reservation, but numerous minor domes and anticlines are present. These smaller structural features were developed during the Bighorn and Pryor Mountain uplift. The outcrop patterns of the formations are indicated in Map 8, which is modified from the State geologic map (Ross and others, 1955).

The Fort Union and Wasatch formations crop out at the surface in the eastern part of the reservation. Most of the coal on or near the

MAP 8

GEOLOGY OF THE CROW INDIAN RESERVATION AND CEDED AREA



reservation is in these two formations. Thin coal seams are found in underlying rocks of late Cretaceous age. The formations in this area dip as much as 4° eastward and generally crop out on the westward-facing slopes of the Wolf Mountains.

Larger faults on the Crow Reservation appear to be directly related to the major folding and warping of the region. The Castle Butte fault, which terminates the Pryor Mountains on the north, has a linear extent of more than 14 miles and a maximum displacement of 2,000 feet. Many flexures in the exposed strata of the reservation undoubtedly reflect subsurface faults caused by torsional effects set up during the Bighorn Mountain uplift. In the Crow coal resource area, minor faults have been identified from interpretation of test-hole data. Displacement along most of these faults is measurable in feet or tens of feet.

The Ceded Area is comprised mainly of plains topography. Major relief rarely exceeds 500 feet in the northern part while exceeding 1,000 feet at some locations in the southern part. Sedimentary formations present in the area are nearly flat-lying, although there is a low regional dip of the beds to the east-northeast. Major structural features are not present in the Ceded Area.

The Fort Union formation of the Tertiary Period and the Montana Group of Upper Cretaceous formations comprise the surface geology of the Ceded Area. The Tongue River member of this Fort Union Formation comprises the majority of the surface on the coal lands located in the southeastern part of the Ceded Area. Below this surface, the middle Lebo shale member and Tullock member crop out along the major drainage systems. The Tongue River member in this area is composed of light-colored shales, massive sandstones and thick coal beds. Upon exposure to the elements, these Cretaceous shales may contribute to a deterioration in water resource quality through the process of leaching.

Recent seismic or earthquake activity has been very minimal in this area, according to a Coast and Geodetic Survey report entitled "Earthquake History of the United States." The oldest records in their report date from 1852.

Minerals

Coal - Several inactive small mines on the reservation and in the Ceded Area produced coal for local use for many years. The total production over the years amounted to only a few hundred thousand tons. The mines were generally near towns or settlements on the reservation.

Table 15 (page 110), a generalized section of the Wasatch Formation and Tongue River member in the Fort Union Formation, shows the designation, relative position, and thickness of the coal beds as they were reported for the reservation in 1966. The full geologic section is present only at the extreme southern end of the Crow coal resource area. Various coal beds and shale and sandstone intervals located higher in the section have been lost through erosion in the central and northern regions.

Recent exploration has proved the coal seams on the reservation to be thicker in some areas than indicated in Table 15.

Table 15 GEOLOGICAL FORMATIONS

Wasatch Formation	Thickness in Feet
Badger bed	7
Interval	180
Local bed	5+
Interval	140
Local bed	5+
Interval	40
Tongue River Member of Fort Union Formation	
Roland bed	0-13
Interval	195
Smith bed	7-20
Interval	70
Powers bed	0-10
Interval	60
Anderson bed	3-27
Interval	65
Dietz No. 1 bed	0-47
Interval	110
Dietz No. 2 bed	0-15
Interval	100
Dietz No. 3 bed	0-6
Interval	50
Canyon bed	6-24
Interval	180
Monarch bed	0-25
Interval	50
Davis, Carney, Wall, or Richard bed	3-32
Interval	100
Carlson or Proctor bed	3
Interval	90
Brewster-Arnold, Sawyer, or R bed	0-20
Interval	50
Popham bed	3
Interval	175
Knoblock or Lee bed	0-20
Interval	60
Schoedel bed	0-14
Interval	40
Rosebud or Q bed	0-28
Interval	7-30
Holt or McKay bed	0-7
Interval	50
Stocker Creek or P bed	0-9
Interval	35-50
Graham or O bed	0-7
Interval	30-65
N bed	0-7
Interval	25-40
Robinson, M, or Coleman bed	0-23
Interval	43
Burley bed	0-5
Interval to base of Tongue River Member	130

A generalized section of the coal seams in the southeastern part of the Ceded Area is reported as follows:

Table 15a

Tongue River Member of Fort Union Formation	Thickness in Feet
Unnamed coal bed	3 - 5'
Interval	70 - 130'
Rosebud-McKay bed	30 -35'
Interval	5 - 10'
Unnamed coal bed	3 - 5'
Interval	50 - 100'
Robinson bed	17 - 23'

The Lebo shale member of the Fort Union formation lies stratigraphically just below the Tongue River member. This shale is from 100 to 300 feet thick and contains only thin coal seams near the reservation. These thin seams are under several hundred feet of cover and have not been mapped because exploration has been confined to the more attractive thick coal seams near the surface of the reservation.

The Big Dirty coalbed in the Lebo shale has been an exploration target of companies drilling in Custer and Prairie Counties, but there is no evidence that it extends into Big Horn County.

The Tullock member contains the oldest rocks in the Fort Union formation and is about 300 feet thick. It too contains thin coal seams which have not been mapped. There are no known coal seams below the Fort Union formation.

Oil and Gas

There has been very little recent oil and gas activity on or near the Crow coal resource area. An average of about six wells are drilled each year in the area, and all but one of the more recent wells have been dry. This well is producing about 50 barrels of oil per day. Production from the Soap Creek, Lodge Grass, and Ash Creek oil fields has been steadily declining during recent years.

About 20 dry oil wells have been drilled near the coal deposits in the Ceded Area. These wells have ranged in depth from 2,500 to 9,177 feet.

Other Subsurface Mineral Products - Important mineral resource other than coal with economic potential in the Crow coal resource area include bentonite, building stone, clays, sand and gravel, and scoria. Of these, bentonite has the most potential for a large mining operation. The bentonite reserves, situated in belts more than 50 feet wide under less than 30 feet of overburden, are estimated to be about 108,000,000 tons. The bentonite is generally inferior in quality to Wyoming bentonite and therefore is not mined at this time. Bentonite mining is not likely unless the market for it increases.

Building stone, clays, sand and gravel, and scoria are used locally but cannot be shipped beyond southeastern Montana and compete in the market. Because of the limited local demand, extraction of building materials probably will not increase significantly under presently indicated trends.

The mining of coal would not conflict in any way with the mining of these other subsurface minerals.

Hydrology

Surface Water Occurence - In the reservation coal area, surface water ponds and small streams drain westward to the Little Bighorn and Bighorn Rivers, eastward to Rosebud Creek and Tongue River, and northward to Tullock and Sarpy Creeks. The Ceded Area is drained by Tullock and Sarpy Creeks into the Bighorn and Yellowstone Rivers respectively. The source of most surface water is precipitation as either rainfall or snowmelt. The few perennial streams derive their base flow from ground water that has been in storage.

The precipitation, characteristics of slope, and types of bedrock make the locality unique; attempts to compare runoff from other areas that have been gaged are tenuous. A generalization from the Bureau of Reclamation report on Eastern Montana Basins of 0.25 inch of precipitation as average annual runoff to streamflow probably is justified.(17) Refinement of this estimate would require installing gaging and weather stations in several drainages and monitoring their discharge and precipitation for several years.

Gaging stations on the major streams have been in operation for various periods of time, but most of their records are not directly applicable to flow from the eastern part of the Crow Reservation or from the Ceded Area. Table 16 on the following page lists the gaging stations that are or have been in operation on streams that flow near or receive water from the eastern part of the reservation and the Ceded Area.

Table 16 Gaging Stations on or near Coal Development Area

Stream and Station	Years of Record	Tributary to	Discharge, Cubic Feet Per Second				
			Average	Maximum	Date	Minimum	Date
Yellowstone River at Billings	1928 to date	Missouri River	6,858	66,100	6/16/67	430	12/12/32
Bighorn River at Kane, Wyoming	1928 to date	Yellowstone River	2,278	25,200	6/16/35	179	7/22/34
Bighorn River near St. Xavier	1934 to date	Yellowstone River	3,550	37,400	6/16/35	112	4/2/67
Little Bighorn River at State Line	1939 to date	Bighorn River	150	2,730	6/3/44	21	12/27/54
Little Bighorn River below Pass Creek	1939-1958; 1959 to date	Bighorn River	205	3,630	6/14/63	12	8/5/61 [3]
Little Bighorn River near Crow Agency	1912-1960 [1]	Bighorn River	248	6,200	9/23/23	0	7/28/21 [3]
Lodge Grass Creek above diversion	1939 to date	Little Bighorn River	49.1	1,130	6/9/64	3.0	1/15/54 [3]
Little Bighorn River near Hardin	1935 to date	Bighorn River	285	4,520	4/2/65	0.2	8/7/61
Bighorn River at Bighorn	1945 to date	Yellowstone River	3,851	26,200	6/24/67	275	11/15/59
Sarpy Creek	1973	Yellowstone River					
Rosebud Creek CSG near Kirby [2]	1960 to date	Yellowstone River					
Tongue River near Decker	1960 to date	Yellowstone River	493	7,480	6/15/67	3.9	8/23/61
Spring Creek CSG near Decker	1958 to date	Tongue River					
Leaf Rock Creek CSG near Decker	1958 to date	Tongue River					
Tongue River at dam near Decker	1939 to date	Yellowstone River	449	7,340	6/15/67	0.0	11/12/69 [3]
Tongue River near Ashland	1966 to date	Yellowstone River	610	5,740	6/18/67	50	11/8/66 [3]
Yellowstone River at Miles City	1928 to date	Missouri River	11,330	96,300	6/19/44	996	12/14/32
Powder River at Moorhead	1929 to date	Yellowstone River	453	23,000	6/17/62	0.0	At times

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[1] Intermittent early records

[2] CSG = crest-stage gage

[3] Also on other days

Source: Water Resources Data for Montana, Part I, Surface Water Records, 1972

Table 17 lists the major reservoirs in the area that are adjacent to the Crow coal resource area.

Table 17 Reservoir Capacity and Annual Flow

Reservoir	Date Completed	Usable Capacity Acre-feet	Average Annual Incoming Flow, Acre-feet
Bighorn Lake near St. Xavier	1965	1,356,000	2,552,000
Willow Creek Res. near Lodge Grass	1945	23,000	35,430
Tongue River Res. near Decker	1938	68,040	357,900

Additional reservoir storage capacity has been considered on the Tongue and Powder Rivers. A dam on the Tongue River at a site near Four Mile Creek would nearly double the storage capacity of the present reservoir and would raise the present reservoir level above the height of the existing dam. A dam at the Moorhead site on the Powder River would impound 100,000 acre-feet and create a reservoir that would extend 30 miles into Wyoming.(17) The average annual flow of the Powder River at Moorhead since 1929 has been 328,200 acre-feet.

About 100 stock ponds and irrigation reservoirs have been built on the Crow reservation in and on the west side of the coal-bearing area.

Stock ponds are numerous also in the Ceded Area, north of the reservation boundary. The maximum areal extent of any reservoir is less than 50 acres; most are less than 10 acres. Most ponds are along the main streams or in small tributary channels. Those in the tributary valleys collect snowmelt and spring rain. The stock ponds may or may not hold water throughout the year. Some contribute water to the ground-water supply by leakage, and some intercept the water table and are recharged from ground water.

Streamflow measurements were made in September 1972, on the Shell Oil Co. lease by W. A. Van Voast along Youngs Creek and Little Youngs Creek, which drain the southeastern part of the Wolf Mountains. Discharge of Youngs Creek at the eastern Crow Reservation boundary was about 3.2 cfs (cubic feet per second). Rosebud Creek was gaged intermittently from May 1968 to May 1969. Its measured minimum flow in 1969 was 14.9 cfs.(18) Most other streams that drain the mountainous eastern part of the Crow Reservation are not perennial. Springs along the sides or bottoms of the valleys will maintain ponds or short reaches of flowing water; however, the water usually disappears into the valley fill within a few hundred yards and becomes underflow.

Quality of Surface Water - Quality of surface water in Youngs Creek and Little Youngs Creek was determined in September 1972 by Van Voast (unpublished data). The water was predominantly a magnesium or magnesium and calcium sulfate type with less than 700 mg/l (milligrams per liter) of dissolved solids. The hydrogen ion concentration, or pH, ranged from about 7.5 to 8.5. Van Voast noted that the streams were sustained by ground water discharge at the time of sampling. Surface runoff from rainfall and snowmelt at other times of the year would alter the percentages of mineral constituents in the water and would modify the dissolved-solids figure.

Surface water quality along Sarpy Creek and East Fork of Sarpy Creek on the Ceded Area has been monitored since October 1972 by consultants to Westmoreland Resources. The water is predominantly a magnesium and calcium-sulfate type containing anywhere from 2,000 to 4,000 mg/l of dissolved solids, depending upon the time of year and amount of runoff present. The hydrogen ion concentration, or pH, ranges from about 7.9 to 8.4. The base flow of these streams is sustained by ground water discharge.

Other streams that drain the potential mining areas have not been sampled for chemical analyses; however, greatly different water types would not be likely. The source areas of the streams are in similar terrains, are underlain with similar rocks, and receive approximately the same amounts of precipitation.

Sediment yield from the Crow coal resource area has not been measured; sediment-sampling stations have been maintained by the U.S.G.S. on Bighorn River at Bighorn intermittently from 1946 to 1970, and on the Little Bighorn below Pass Creek from 1969 to 1973. Continuing sampling stations are maintained on the Little Bighorn near Hardin and on Beauvais Creek near St. Xavier. A study of the eastern Montana basins showed that the area would yield about 400 tons of sediment per square mile per year.(17)

The amount of sediment yield is directly affected by the topography, vegetative cover, land use, amount of water available at a given time, and climate. If an area has been denuded of vegetation and the soil has been disturbed, an intense rain may remove several times the amount that would come from an adjoining forest or grassland.

Ground Water Occurrence - Ground water in the eastern part of the Crow Reservation and in the Ceded Area is obtained from scattered stock and domestic wells and springs. In Rs. 36-38 E. within the Crow Reservation, topographic maps show over 250 wells and springs, most of which are used for stock water, and about 100 homes, most of which have wells or springs as their water source. In the Ceded Area also, wells and springs furnish household and stock water. A record of selected wells in the Ceded Area and adjacent to the Crow Reservation is presented in Appendix J.

Ground water in the Crow coal resource area is obtainable from several aquifers. Aquifers frequently used include alluvium and colluvium (slopewash) of Recent age, clinker and baked shale and sandstone of Eocene age, the Wasatch Formation of Eocene age, and the Tongue River and Tullock Members of the Fort Union Formation of Eocene age.

Alluvium and Slopewash - These unconsolidated aquifers are of Recent age and are readily accessible sources of ground water. The alluvium is confined to stream valley bottoms and flood plains. Its composition is not uniform. Characteristically, it includes well sorted to poorly sorted beds of gravel, sand, and clay. The beds are usually of limited areal extent and thickness. Where well sorted, the sand and gravel beds are potentially dependable water sources. Most recharge to the alluvium is likely to be supplied from associated streams or from precipitation on the alluvial areas.

The slopewash, which is talus and debris from the sides of the valleys, may be a dependable source of limited water for household and stock use. The deposits consist of sand, clay, and clinker fragments that range from poorly sorted to well stratified (rarely). Water in the slopewash is derived from precipitation and from infiltration of surface runoff; some is contributed from adjacent bedrock aquifers.

Clinker - Ground water in clinkered surface material usually is perched and of limited extent. Characteristically, it emerges as seeps along the edges of the larger interstream divides. Generally the water evaporates or is transpired by vegetation growing at the contact between the clinkered material and underlying strata. In some places, seepage from the base of the clinkered material is piped to stock tanks. Yields seldom exceed one gpm (gallon per minute). Wells that obtain water from clinkered material may yeild one to two gpm.

Aquifers in the Wasatch Formation and the Tongue River Member of the Fort Union Formation are sandstone and coal beds. In adjacent areas, yields are as much as 50 gpm. Most wells drilled for household or stock supplies yield much less, however.

The Lebo Shale Member of the Fort Union Formation includes few water bearing sandstones, and the contained water is normally too highly mineralized to be usable for either stock or domestic supplies. The Tullock

Member of the Fort Union and the underlying Hell Creek Formation are lithologically similar in that they consist principally of sandstones and interbedded shales; the Tullock also includes minor coal beds. These sandstones and coal beds are likely to be dependable aquifers.

Most water-bearing strata beneath the Hell Creek Formation contain water that is too saline to be usable for domestic or household supplies. Exceptions are the Madison Limestone and the Red River Formation. These strata are deeply buried limestone formations, and where they are canvernous they may yield copious quantities of water. Few water wells have been constructed in either formation, however.

Ground Water Recharge - In the Crow coal resource area, potential recharge to ground water is derived from several sources but depends on specific circumstances. Recharge from snowmelt can occur only if the soil zone beneath the snow or downslope along the runoff paths of melt water is not frozen and is capable of accepting the influent water and also of transmitting it beyond the soil-moisture zone. If these requirements are not met, the melt water becomes surface runoff or soil moisture. Recharge from rains also can occur under certain climatic and soil conditions. A rain in early spring will saturate the soil first; additional water potentially passes through the soil to the water table and becomes ground water. Rain during the growing season may contribute nothing to the ground-water body but will replenish soil moisture. Fall rains, after the first killing frost but before the ground is frozen, may contribute to the ground water supply. Intense rains, regardless of the season, may make more water available than the soil can accept and transmit; the excess water is then rejected and becomes part of the surface-water runoff.

Most valleys in the Crow coal resource area contain intermittent streams that may lose water by infiltration into the underlying alluvium. Many stock ponds in the area are unreliable; they lose water by evapotranspiration, seepage, or both. Recharge to ground water from surface-water sources usually occurs during late spring and early summer. During the remainder of the year, the coulees are either dry or flowing streams are supplied by ground-water underflow. Late winter thaws may make water available, but frozen soil beneath the watercourses usually prevents infiltration of the melt water.

Ground-water Movement - Water in the shallow aquifers is supplied by local precipitation and seepage losses from streams to these aquifers. It descends through permeable material until it reaches a less permeable barrier. From this point, it moves laterally along the most easily accessible route in response to gravity. Most aquifers are layered, and movement along or within a layer is easier than movement through layers of different permeabilities. A shaly layer at the base of a sandstone stratum, for example, will tend to inhibit downward movement of water and will deflect the water to follow paths within the sandstone. Water in the formations that crop out in the Wolf Mountains is moving slowly downslope toward points of discharge.

Ground water is discharged from the shallower aquifers in the Crow coal resource area at places where the water table intersects the land surface, where it can migrate to another aquifer, or where it is removed artificially from wells. Natural discharge is from springs, seeps, and swamps, directly to streams and other aquifers. Very little water is pumped from wells in the Crow coal resource area.

Water in the deeper aquifers that do not crop out in the Wolf Mountains is similarly moving from areas of recharge to points of discharge, but most of the recharge areas lie west of the Crow coal resource area. The rate of movement in many of these aquifers is so slight that the water can be considered to be static; in fact, much of the water probably has been trapped within the formations virtually since they were deposited.

Ground-water Storage - Data concerning the aggregate thickness of water-bearing strata and their average porosity and permeability are lacking. However, if one assumes that the average porosity of the sandstones in the Tongue River Member of the Fort Union Formation is 10 percent (which would not be an unreasonable figure), and the average thickness of sandstones throughout the member in the Wolf Mountain area is 250 feet (rough estimate), the stored ground water per square mile would be about 5.2 billion gallons, or 25 acre-feet per acre. If the aquifers were drained, much of this water would be retained in the sandstones by adhesion to the fine-grained particles due to capillary action. A well that completely penetrated the Tongue River Member would remove water from only a fraction of the aquifer, and that only within a radius of a few hundred feet.

Van Voast (unpublished data, 1973) made transmissivity tests on the "M" coal bed in the Decker area, which lies about 10 miles east of the

Shell lease area. Transmissivity values ranged from 140 to 550 gallons per day per foot.

Quality of Ground Water - Very little data are available concerning the chemical quality of the ground water in the Crow coal resource area. Information on ground water quality present in several aquifers of the Sarpy Creek area is published in the final environmental statement (FES 74-8) for the "Crow Ceded Area Coal Lease, Westmoreland Resources Mining Proposal." (18a) Unpublished data collected by Van Voast along Youngs Creek indicate that the shallow ground water is predominantly a calcium or magnesium-sulfate type. This is similar to results of studies of the Northern Cheyenne Indian Reservation, (16) where samples of water from the Tongue River Member of the Fort Union Formation were found to be either magnesium and calcium sufate or sodium bicarbonate types. A list of representative chemical analyses of water from wells near the Crow Reservation coal area is contained in Appendix K.

According to Renick, water in the Tongue River Member of the Fort Union less than 125 feet below the land surface is likely to be a "hard" calcium or magnesium sulfate type, whereas that below 125 feet from the surface is normally a "soft" sodium bicarbonate type. (12) He attributed this phenomenon to natural softening by base exchange that occurs as the downward percolating water comes into contact with the interbedded shales in the formation.

Ground water in the formations of Cretaceous age beneath the Fort Union has been tested in the Northern Cheyenne Indian Reservation area. (16) Most of the ground water is a very saline sodium chloride type. The aquifers of Mississippian age--specifically the Mission Canyon or Madison Limestone--have not been tested on the Crow Reservation. A well drilled to the Madison at the Westmoreland Resources mine site, directly north of the reservation, and a well at Colstrip, northeast of the reservation, both encountered calcium sulfate type water. A well in the Soap Creek oil field, west of the study area, also flowed calcium sulfate type water from the Madison.

Water Pollution Sources

Surface Water - Pollution of surface waters on the Crow coal resource area includes plant, animal, and inorganic alteration or accretions. Algal growth, decaying vegetation, and water-borne seeds or growth tend to alter stock ponds and, to some extent, the streams. Cattle and other animals (both live and dead) are sources of high nitrate, urea, and pathogenic bacteria in ponds and streams. Runoff from slopes yields not only soil and rock material but also biologic debris to surface waters.

Ground Water - Pollution of ground water is mostly attributable to poor well completion or to poor choice of well sites. An improperly cased well that is not sealed tightly is subject to contamination from insects and small animals. Wells cased with poor quality material may deteriorate and permit infiltration of contaminated water. Some wells are cased with only a stub of casing above the land surface, or even below the surface, allowing runoff to enter the well. Shallow wells constructed in permeable surficial material and in proximity to outhouses or feed lots may have high concentrations of nitrate or fecal coliform bacteria in the water. Wells perforated in several water-bearing zones may become conduits through which poor quality water can migrate from one aquifer to another.

Water Rights

The development of energy conversion plants on the Crow Reservation will require very substantial quantities of water. In the coal development area, these quantities are only available from surface sources. Since water is a critical resource of limited supply in the area, the concern for its equitable and effective utilization becomes a major issue in any developmental scheme. Water rights direct themselves to this issue.

The question of water rights involve serious jurisdictional issues, appropriation doctrines and interstate compacts. Representatives of Indian tribes from five western states have gone on record that they consider "that the American Indian tribes of the Northern Great Plains have the prior and paramount rights to the waters of all rivers, streams, or other bodies of water, including all tributaries thereto, which flow through, arise upon, underlie or border upon their reservations." 1/

On the other hand, the State of Montana and the three state (Wyoming, Nebraska, North Dakota) Yellowstone Compact also lay claims to waters which flow through the Crow Reservation. On the Federal side, the Bureau of Reclamation assumes water management jurisdiction for impounded waters in Bureau constructed reservoirs.

The following discussion describes the legal and jurisdictional complexity of the issues involved. As large scale energy conversion

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1/ "Declaration of Indian Rights to the Natural Resources in the Northern Great Plains States," prepared by Member Tribes in the Native American Natural Resources Development Federation of the Northern Great Plains, June 1974.

develops on or near the reservation, these issues will require adjudication.

Indian Water Rights

The treaties with the Indians are generally silent about rights to use of water, but the Indians' water rights have been established by judicial decree. There have been a series of cases which involve the doctrine of the Federal reserved right to the use of the water which has been withdrawn or reserved by the Federal Sovereign for specific purposes such as Indian Reservations, parks, forests, fish and wildlife refuges and military posts.

The Indians' prior and paramount rights were sustained in the United States Supreme Court case familiary known as the "Winters Doctrine," Winters v. United States, 207 U.S. 564 (1908). The Court held in that case that the right to use of water from the Milk River in the State of Montana, a stream which bordered upon the Fort Belknap Indian Reservation, was reserved by the government in the treaty for the benefit of the Indians of that reservation.

The Winters Doctrine embraces reservation rights whether created by treaty, statute or executive order, before or after statehood.

- U.S. v. Walker River Irrig. Distr., 104 F.2d 334 (1939)
- Ariz. v. Cal., 373 U.S. 600

The waters reserved are exempt from appropriation by non-Indians pursuant to State law.

- Winters v. U.S., supra
- U.S. v. Ahtanum Irrig. Dist., 235 F.2d 321 (9th Cir. 1956)

The courts have consistently held that the nature of the right was such that sufficient water was reserved for the present and future needs of the Indians, whatever the use and without limit.

- Ariz. v. Cal., 373 U.S. 546 (1963)

It is the definition of the purpose of each reservation that requires careful consideration; the language of the various treaties speaks in terms of providing a permanent home or place to live, free from encroachment by the non-Indian.

- See Treaty of Fort Bridger, July 3, 1858 (15 Stat. 643)

Although the fundamental rules of Indian treaty construction have been variously stated, there are essentially three well defined and well established rules.

The first fundamental rule is that "treaties with Indians must be interpreted as they would have understood them."

- Choctaw Nation v. Oklahoma, 397 U.S. 620, 630 (1970)

- Jones v. Meehan, 175 U.S. 1, 10-11 (1899)

- United States v. Shoshone Tribe, 304 U.S. 111, 116 (1938)

- United States v. Winans, supra

A second rule of Indian treaty construction is that doubtful expressions are to be resolved in favor of the Indian parties to the treaty.

- McClanahan v. State Tax Comm'n of Arizona, ______ U.S. ______, 36 L.Ed.2d 129, 137 (1973)

- Carpenter v. Shaw, 380 U.S. 363, 367 (1930)

- Standing Rock Sioux Tribe v. United States, Ct. Cl. 813 (1963)

A third important canon of Indian treaty construction is that Indian treaties are to be constructed in favor of the Indians.

- Choctaw Nation of Indians v. United States,
  318 U.S. 418, 431-432 (1943)

- Tulee v. Washington,
  315 U.S. 681, 684-85

- United States v. Shoshone Tribe, supra

Executive order reservations are no different than treaty reservations as far as the question of Indian water rights is involved.

- Ariz. v. Cal., supra

- U.S. v. Walker Irrig. Dist., supra

Language in a Federal statute affecting the rights of Indians is to be construed in the same manner as is language of treaties with Indians.

- Squire v. Capoeman,
  351 U.S. 1, 6 (1956)

Henceforth, it can be argued that the Indian may do the same thing with the reserved lands of his home as the white man can do with his home lands, which includes plans for use and development of the irrigable acres and minerals; creating communities; preserving the environment for fish and game; preserving minimum stream flows; providing for recreation; establishing industries, and so forth. (19)

Water Laws of Montana

Although it has not been tested in the courts, the State of Montana assumes its water right laws apply to the Ceded Area, particularly if the waters involved are diverted outside of the Crow Reservation. If this is accepted, an understanding of basic Montana law and its doctrine of prior appropriation is relevant.

Appropriation Doctrine in Montana

Prior to 1973, Montana used the "first in time, first in right" doctrine as the principal criteria for determining or recognizing water rights. In 1973, the legislature repealed prior laws relating to water rights and enacted the "Montana Water Use Act," which is found in Sections 89-865 through 89-8-102, Revised Codes of Montana 1947, as amended. The basic provisions of this Act follow.

Ownership - Any use of water is a public use, and the waters within the State are the property of the State for the use of its people and are subject to appropriation for beneficial uses as provided by the act. Administration, control, and regulation are required in implementing article IX, section 3(4) of the Montana constitution, and the 1973 legislature established a system for the administration, control, and regulation of water rights, as well as a system of centralizing records.

Existing Rights - The act recognizes existing rights pursuant to article IX, section 3(1) of the Montana constitution and provides a method for determination of existing rights. This includes gathering of data from court decrees, declarations of existing rights filed under section 8 of the act, and various other notices of appropriation and records of declarations and statements filed pursuant to the act, as well as findings from investigation and surveys made by the Department of Natural Resources and Conservation.

Appropriation of Water - After the effective date of the Montana Water Use Act, no person may appropriate water except as provided by the act. Adverse possession, prescriptive right, or estoppel are not recognized under the new act.

An application for a permit is filed with the Department upon publication and notice as provided in the act. Objections must be filed within a particular time and hearings may be held on valid objections. The permit may be issued by the Department for less water than requested, but in no case for more water than can be beneficially used without waste for the purpose stated. The Department may limit time for commencement of the appropriation works, completion of construction, and actual application of water. The permit may be revoked if these time limits are not met by the appropriator. Upon application of water to beneficial use within the time allowed, the Department will issue a certificate of water right.

Reservoirs - Appropriation of water by means of a reservoir requires a permit. Through a section in the act regarding the reservation of waters, the State or any of its political subdivision or agencies, or the United States or any of its agencies may apply to reserve waters for existing or future beneficial uses, or to maintain a minimum flow level or quality of water throughout the year.

Priorities - Between appropriators, first in time is first in right. Priority of appropriation does not include the right to prevent changes by later appropriators such as increase or decrease of streamflow, or the lowering of a water table, artesian pressure or a water level, if the water right of the prior appropriator can be reasonably exercised under the changed conditions.

Priority of appropriation under the act dates from the filing of an application for a permit with the Department, except as otherwise provided in the reservation of water, supra. Priority of existing water rights before the effective date of the act is determined as indicated in the section of determination of existing rights, supra.

Changes in Appropriation Rights - Change in the place of diversion, place of use, purpose of use, or place of storage must receive prior approval from the Department.

Transfer of Appropriation Rights - Right to the use of water under a permit or certificate of water right shall pass with the conveyance of the land or transfer by operation of law unless specifically exempt without loss of the priority.

An appropriator may not sever all or any part of an appropriation right from land to which it is appurtenant, or sell the right for other purposes or to other lands, or make the right appurtenant to other lands without obtaining prior approval from the Department.

Abandonment of Appropriation Right - If an appropriator ceases to use all or part of his right with intent to wholly or partially abandon the right or ceases to use the right according to its terms and conditions with intent not to comply, the appropriation right shall, to that extent, be deemed abandoned and shall immediately expire.

If an appropriator ceases to use all or part of his appropriation right or ceases to use it according to its terms and conditions for a period of 10 successive years, and there is water available for use, there is a prima facie presumption that the appropriator has abandoned his right in whole or for the part not used. The provision on abandonment of appropriation right does not apply to existing rights until they have been determined in accordance with the act.

The Department shall petition the District Court for declaring appropriation rights to be abandoned, and the burden of proof is on the Department to establish by a preponderance of evidence that the appropriation has been abandoned.

Supervision of Water Distribution - From the effective data of the act, District Courts shall supervise the distribution of water among all appropriators, including the supervision of water commissioners appointed prior to the effective date of the act. The Department may petition the Court to determine existing rights in a dispute between parties. Any controversy between appropriators from a source which has been the subject of a general determination of existing rights shall be settled by a District Court which issued the final decree. The order of the District Court settling the controversy may not alter the existing rights and priorities established in the final decree. In cases involving permits issued by the Department, the court may not amend rights established in the permits or alter any terms of the permits unless the permits are inconsistent or interfere with rights and priorities established in the final decree.

Prevention of Waste - If the Department believes that a person is wasting water, using water unlawfully, or preventing water from moving to another person having a prior right, it may petition a District Court to regulate the controlling works of an appropriation or secure water to a person having a prior right or order the person responsible to cease and desist. The Department may also direct its own attorney or request the Attorney General or County Attorney to bring suit to enjoin such waste, unlawful use, or interference.

Inspections - Any employee or agent of the Department authorized by the Director may enter upon any land to carry out the purpose of the act following reasonable notice given to the landowner.

Legal Assistance - When requested by the Department, the Attorney General and the County Attorney shall perform legal services to carry out the purposes of the act. The Department may also employ legal counsel to enforce the act and conduct proceedings under it.

If a Montana citizen who is an appropriator becomes involved in a controversy within an agency of the Federal Government or other state, the Department may intervene and provide necessary legal assistance to the Montana citizen.

Hearings - Any person aggrieved by a final decision of the Department is entitled to a hearing before the Board.

Penalties - Violation or refusal or neglect to comply with sections regarding the appropriation of water, changes in the appropriation of water, or transfer of appropriation rights or of any order of the Department or rule of the Board is guilty of a misdemeanor.

Water Compacts

The only compact which apparently governs the usage of Crow Reservation surface waters is the Yellowstone Compact. This compact was negotiated among the States of Montana, Wyoming and North Dakota to allocate the unused and unappropriated waters of the Yellowstone River and its interstate tributaries.

Quoting from Water Laws of Montana, 1965 (amended in 1969) under Article V of the Yellowstone Compact: (21)

ARTICLE V

A. Appropriative rights to the beneficial uses of the water of the Yellowstone River system existing in each signatory state as of January 1, 1950, shall continue to be enjoyed in accordance with the laws governing the acquisition and use of water under the doctrine of appropriation.

B. Of the unused and unappropriated waters of the interstate tributaries of the Yellowstone River as of January 1, 1950, there is allocated to each signatory state such quantity of that water as shall be necessary to provide supplemental water supplies for the rights described in paragraph A of this Article V, such supplemental rights to be acquired and enjoyed in accordance with the laws governing the acquisition and use of water under the doctrine of appropriation, and the remainder of the unused and unappropriated water is allocated to each state for storage or direct diversions for beneficial use on new lands or for other purposes as follows:

1. Clarks Fork, Yellowstone River
    a. To Wyoming 60%
       To Montana 40%
    b. The point of measurement shall be below the last diversion from Clarks Fork above Rock Creek.

2. Big Horn River (Exclusive of Little Bighorn River)
    a. To Wyoming 80%
       To Montana 20%
    b. The point of measurement shall be below the last diversion from the Bighorn River above its junction with the Yellowstone River and the inflow of the Little Bighorn River shall be excluded from the quantity of water subject to allocation.

3. Tongue River
    a. To Wyoming 40%
       To Montana 60%
    b. The point of measurement shall be below the last diversion from the Tongue River above its junction with the Yellowstone River.

4. Powder River (Including the Little Powder River)
    a. To Wyoming 42%
       To Montana 58%
    b. The point of measurement shall be below the last diversion from the Powder River above its junction with the Yellowstone River.

The Yellowstone Compact apparently governs part of the water which arises on the reservation. The Little Bighorn River and its tributaries were specifically excluded from the compact, as were all adjudicated water rights with priority date before 1950.

Few of the water rights on the reservation prior to 1950 are adjudicated; therefore, all surface water on the reservation except the Little Bighorn River appears to be included in the compact. However, Article VI of the compact provides that it does not apply to any Indian water rights. Therefore, it would not interfere with these rights.

Crow Indian Irrigation Project

The Crow Indian Irrigation Project and non-project operated units, Bozeman Trail Ditch, Two Leggins Drainage District, Two Leggins Water Users Association and private or individual irrigation ditches on the Crow Indian Reservation, Montana, operate under Indian water rights, based on the Winters Decree and Power's Decision. Although the State of Montana has adopted a new Water Rights Law for both surface and underground waters, the Crows have not accepted enforcement of State jurisdiction on the Crow Indian Reservation.

The lands within the prescribed project are situated along the Bighorn River, Little Bighorn River, Pryor Creek, and Lodge Grass Creek, which are all tributary to the Yellowstone River. There are nine project-operated units scattered over an area roughly 50 miles by 60 miles in size. The lands contained within the project may be categorized as follows: (22)

Project when completed	46,460 Acs.	
non-project operated units when completed	4,152 Acs.	
Estimated Total		50,612 Acs.
Est'd. Indian Trust or Tribal Land	33,933 Acs.	
Est'd. Fee Patent or non-Indian Land	16,679 Acs.	
Est'd Total when Project Completed		50,612 Acs.

Court Filings

Ceded Area: Appendix L contains a listing of surface water appropriations by stream source for the Crow Ceded Area. An examination of these water rights appropriations indicates that nearly all the streams are appropriated beyond their hydrologic capability. These filings were compiled from Big Horn and Treasure County records and reflect only those water filings recorded by the State of Montana.

Crow Reservation: A listing of recorded water filings on the Crow Reservation is given in the Report on inventory of Water Resources, Crow Indian Reservation, Montana. These filings were compiled from Big Horn and Yellowstone County records and reflect only those water filings that have been recorded by the State of Montana. Additional appropriations have been made on the reservation; however, the reservation records are not available as public information.

Appendix L shows the list of surface water appropriations, by stream source, for the eastern portion or the Crow Indian Reservation. Examination of the water right appropriations for these streams indicate that nearly all these streams are appropriated beyond their hydrologic capability. However, the vast majority of these filings were made before

1900 and are not active at the present time.

No attempt is made to distinguish Indian rights from non-Indian rights since these rights have changed in ownership many times. Records of land ownership and accompanying water rights are essentially non-existent.

Regarding priority, it is important only to realize that the U. S. Supreme Court has ruled Indian rights are senior to all others, except the very few that were acquired before the reservation was established in 1868. There are no such filings on record with the State of Montana on the Crow Reservation.

It has been decreed that Montana and Wyoming State laws cannot be invoked to limit rights on Indian trust lands, except insofar as the United States has given its consent. Whereas it has been the practice of former superintendents at the Crow Agency to post notice of beneficial use, in accordance with state statutes, it was done primarily for the purpose of putting the appropriators on notice that the Indian rights supersede the State rights.

Allocation of Bighorn River Water

Appendix M (23) shows the present allocation of natural flow in the Bighorn River between the States of Montana and Wyoming. It is based on the period of study from July 1, 1959 through January 31, 1962, as interpreted by the Bureau of Reclamation.

Appropriation of water from storage in Boysen and Yellowtail reservoirs, on the Bighorn River, is completed or nearing completion. Appendix N outlines the status of executed contracts for industrial water service marketing from these reservoirs. Those appropriations which contemplate the diversion of water arising on, adjacent to, or running through the Crow Indian Reservation will be subject to Indian water rights under the Winter's Decree.(23)

In summary, the environment on the Crow Reservation prior to coal development was characterized by gradual change. Population levels were fairly constant, the economic base was agricultural, and the society was rural or small town oriented. The large part of the change occuring was the product of modification or shifts in the agricultural base and some increase in commercial recreation activity.

The opening of the Westmoreland mine may herald a new era. At the present time most of the impact on the Crow Reservation and people is one of increased employment and income opportunities. As coal development progresses and draws closer to the heartland of the reservation, much sharper and acute impacts will be felt.

CHAPTER III

ENVIRONMENTAL IMPACTS

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ENVIRONMENTAL IMPACTS

The mining of coal which will likely take place on the Crow Indian Reservation and the Ceded Area will have primary impact in Big Horn and Treasure Counties of Montana and in Sheridan County, Wyoming. There is also a high probability of considerable spill-over of socio-economic impacts into Rosebud and Yellowstone Counties, particularly in the communities of Forsyth and Billings. Although the majority of the land disturbed by mining will be located in the permitted area, land use impacts will be intense throughout the Little Bighorn valley, with associated effects on the entire environment of that area.

Qualifying Considerations in Estimating Impact

The degree of impact of any development on a given reservation and/or region is dependent on: (1) the complexity, scale and size of the development; (2) the rate or velocity (time span involved) of the development; (3) the manpower requirements; (4) the efficacy of controls placed upon the mining and community development; and (5) the adaptability of the reservation's institutions to the emerging society. These are dynamic factors which require continuing and flexible analyses. The recent increases in projected mining levels on the Westmoreland leases strengthen the statement's original impact assumptions that coal development would occur first on the Ceded Area. This change in projected development will have no significant effect on the continuing validity or applicability of this statement.

In attempting to isolate the impact on the Crow Reservation, it is important to remember that it cannot be considered a developmental island. Very intensive and extensive coal development will be taking place in areas immediately adjacent to this reservation. These adjacent developments will be in inter-regional and in intra-sectoral competition with the reservation, as well as with other areas, for manpower, housing and public services, and other facilities. This will contribute greatly to internal and external socio-economic pressures, while seriously curtailing opportunities for impact dispersal over adjacent areas. For instance, the massive coal development that is planned and underway in the areas immediately adjacent to the Crow Reservation, such as the Decker-Birney, Gillette, and Colstrip areas, will tend to magnify the impact on the Crow Reservation because of their close proximity and intense competition for services.

The rate or velocity of development will affect the capacity of the reservation's institutions to adapt to its changing needs and aspirations. The reservation's capacity to effectively react to the demands of development will be determined, to a large degree, by the time and pressures involved. High velocity development will severely test any rural area's effective reaction as mobs of construction workers flock into the rural growth area.

The manpower requirements of a development determine the need for in-migrant labor and set future population levels. Rapid population increases, particularly when associated with high levels of in-migration, may severely test existing facilities and institutions. This may create community division and social conflict unless appropriate steps are taken to forestall such events.

The controls or restrictions placed on mining and community development may significantly affect the complexity, velocity and manpower requirements of coal utilization by acting as a curb on development. However, if such controls are only local, not regional, they act as relatively ineffective insulators against development problems.

The adaptability of the reservation's institutions to changes brought about by coal development is probably the most critical factor to orderly and beneficial growth. The ability of these institutions to conceive, plan, and implement programs which will maximize benefits and minimize disadvantages will be the major mitigating force against undesirable environmental and social change.

The artifacts of the human past, the present socio-economic patterns and structures as well as the future of socio-economic development will be deeply affected by the impacts of coal development on the Crow Reservation.

THE HUMAN ENVIRONMENT

The Impact on Communities

The only mining plan presently available makes no provision for a company-developed town, and other mining interests have not indicated a need or interest for such an approach. Therefore, it is not likely that new organized towns will be a part of the development. It is assumed, then, the commercial and residential facilities will be developed in the existing towns presently serving the area. Hardin, Montana, will likely feel the impact most extensively and is presently undergoing a minor boom. Sheridan, Wyoming, which is presently experiencing rapid growth from coal development in adjacent areas, is also expected to feel additional extensive socio-economic impacts, particularly at the projected high level of development on the Crow Reservation. The Little Bighorn Valley and its two major Indian communities, Lodge Grass and Crow Agency, will feel moderate impact at both development levels. This moderate impact is based on the assumption that the Crow Tribe will be able to plan and implement effective land use controls.

Employment and Income

As indicated in Table 3 (page 23), the low level of development--three mines producing 20,000,000 tons of coal annually--is expected to result in the direct employment of 450 workers in three mines. The high level of development, with the coal utilization plants and a production of 90,000,000 tons, has been estimated to result in the direct employment of as many as 6,505 workers in six mines, two gasification-power plant complexes, and a liquefaction-power plant complex. Either level of development is likely to require a period of years with high-level development requiring two to three decades to reach the assumed level.

Service and associated activity will result from the coal development and the multiplier effect will bring further expansion to employment opportunities in the southern Montana and northern Wyoming areas. Since the reservation area does not have a complete array of services, the local employment multiplier is estimated to be 2.0; that is, an increase of one worker in a basic industry will add one additional worker in support industries.

However, the more usual employment multiplier of 2.7 for Montana (Montana Department of Planning and Economic Development Studies) will still apply in the larger geographical region including Billings. In other words, another 0.7 of an employee will find an associated job somewhere in southeastern Montana or northern Wyoming, but outside the boundaries of Big Horn County, Montana, and Sheridan County, Wyoming, as a result of each new mining job. Associated mining jobs such as quarry operators and transportation workers are included in the multiplier effect. The additional numbers of education, health care, and law enforcement personnel discussed later in the social section are also included in the multipler effect.[1/]

The employment impact on the Crow Indian work force will be even greater than for the area as a whole. It is assumed that there will

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[1/] For detailed information on direct and indirect employment by specific location, see Appendix W.

be an agreement between the Crow Tribe and the mining companies assuring that preferential treatment will be given the Crow Indians in job placement. Under such an agreement, the Crow Tribal Council could assist in the recruitment and placement of the members of the Crow Tribe who desire work with the mines and energy plants and are capable of filling the job openings.

With either level of coal development, long-range employment opportunities for Indians at the mines and energy plants appear favorable. In fact, a sizable labor force will have to be brought in (especially at the higher assumed development level) to fill the jobs available.

Projected levels of Indian employment are 225 at the low level and 825 at the high level. This assumes employing not only all Indians currently unemployed and seeking work, but at the high level it also includes returning Crow Indians and some transferring of Crow workers from present positions. It is assumed that many in the Crow labor force will remain in occupations that are not associated with the projected levels of coal extraction and conversion. If, in fact, coal related industrial employment does appeal to the Indian workers, then more than the assumed 825 may eventually be employed in such occupations.

There is a certain amount of underemployment among those Indians considered employed, so steady jobs at the mine or energy plant sites could alleviate this problem. An important point that must be considered is that relatively high-paying mine or energy jobs may attract workers from lower-paying or less desirable jobs, thus leaving job vacuums in other sectors, both on the reservation and in adjacent areas.

On the other hand, some Indians and non-Indians returning to the reservation area, if jobs were available, would tend to reduce local employment opportunities, but might add considerable stability to the labor force. During the construction phase for the low level of development, employment of up to 450 people during peak periods will occur, while under the high level, 6,505 people will probably be adequate to take care of the construction and operating phases, because the construction period will be spread out over a long time span.

The Westmoreland mine in the Ceded Area is presently employing a total staff of 97 of whom 47 are Indians, including seven in administration. It is anticipated that most of those employed in construction will be shifted to the other jobs in the mine or to other mines, now that the Westmoreland construction phase is completed. It is assumed that this mine could employ most of the surplus Indian labor force who were seeking work in mining occupations.

There will be a time period during the early stages of mining development when Indian employment will not be up to its full potential while certain critical skills are being developed. Later, as the Indian training program develops a fully capable work force, the Indians will move into openings created by work force turnover and by further expansion of the mining operations.

A manning table developed by the Bureau of Mines, included in Appendix O, indicates the types and number of jobs that would be available in each of two strip mines producing a total of 10,000,000 tons of coal a year. Appendix M presents a manning table, taken from the El Paso Natural Gas Company's Burnham Coal Gasification Complex, which indicates job requirements for a gasification plant producing 250 million cubic feet of synthetic gas per day. These tables were considered in estimating personnel requirements for the Crow coal development.

A manning table was not available for the liquefaction plant, which is to produce 200,000 barrels of gasoline per day, so labor requirements similar to the gasification plant were assumed. Power plants are associated with the gasification plants at the projected high level of development, so employment for these plants was also added to the other labor requirements.

Individual incomes will be greatly affected by these levels of development. The projected direct employment in coal development would be 450 and 6,505 respectively at the low and high levels. This could result in aggregate employment income ranging from $5,400,000 to $78,060,000 annually, based on the approximate average annual wage rate for semiskilled persons in 1973. The Indian portion of this employment income would be $2,700,000 and $7,860,000 annually depending on the development level. The Indian wage rate would no doubt move up to higher levels as skill levels increased.

Average salaries for all personnel in the projected mines and plants, based on recent data, are estimated to be between $12,000 and $13,000 a year.

Tribal revenues and individual royalty rates are presently under negotiation, and indications are that the rate will be 40¢ per ton or more. Assuming the 40¢ price, the Crow Tribe could receive annual royalties of $8,000,000 at the low level and $36,000,000 at the high level of development.

The application of an income multiplier of 1.9 to the direct coal income (royalty and wages including non-Indian wages) indicates a total local income ranging from $25,460,000 to $216,714,000 annually, depending on the level of development. A further multiplier effect would apply in surrounding areas of southeastern Montana, including Billings, and in northeastern Wyoming, particularly Sheridan, in an amount ranging from $8,040,000 to $68,436,000 annually. Here again, the amount would be dependent on the development level.[1/]

Furthermore, these income multiplier effects will increase over time as more complete service and supply sectors develop locally. That is to say, the magnitude of the local multiplier will likely increase to over 1.9 in the more distant future.

There will be some additional economic impact from direct operational expenditures by the coal mining and energy plant contractors. The effect of these operational expenditures on the local economy will depend on the degree to which specialized service and supply inputs for

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[1/] The same multiplier cannot be used for employment and income because the service industry payscale in Montana is lower than the anticipated wage rate for the direct mine employment. The employment multiplier that was used was 2.0 locally with an additional 0.7 for the remainder of southeastern Montana; the income multipliers were 1.9 and 0.6.

the coal mining operation are available within the area. In any case, they constitute a very substantial portion of the total multiplier effect.

Changes in the employment and economic status of the people resulting from coal development in the area will bring social changes. The following discussion considers social effects likely to result from Crow coal development.

Population Change

The increase in employment opportunities will no doubt result in a significant increase in population. The major portion of the non-Indian population increase will be in the Sheridan, Wyoming, and Hardin areas. The Yellowstone River Valley, including Billings and Forsyth, will absorb a significant portion of the population increase.

The location of the anticipated increase in population is shown in Map 3.

It can readily be seen that two-thirds of the non-Indian population increase will be in the Hardin and Sheridan areas. Lodge Grass and the Little Bighorn Valley, the major Indian communities, will have less than 10 percent of the total increase in non-Indian population, and conversely, over 50 percent of the increased Indian population will be concentrated in them.

An increase in population levels is anticipated for both levels of development, although the increase will be modest at the low level (about 10 percent) since it is anticipated that the employees will be drawn primarily from the existing population.

However, at the high level of development, it is anticipated that there will be substantial additional population, which either would ordinarily have migrated to other areas to obtain employment or will be newcomers. This increase is shown in Table 18. This increase, as shown in Table 18, is approximately 123 percent of the present 10,057 population (1970 Census) for the immediate reservation area. For the broader area impacted, it constitutes an increase of 38 percent over the 1970 population of 113,337.

Table 18 Population Increase Due to Coal Development
Crow Coal Resource Area
High-Level Development [3]

Location	Indian			Non-Indian		
	Employees	Families	Population	Employees	Families	Population
Hardin	100	71[1]	257[2]	2,946	2,104	7,616
Lodge Grass	250	178	644	780	557	2,016
Little Bighorn Valley	200	143	518	830	593	2,147
Sheridan, Wyoming area	50	36	130	7,886	5,633	20,391
Yellowstone River	25	18	65	4,046	2,890	10,462
Northern part of Crow Reservation	200	143	518	250	179	648
	825	589	2,132	16,738	11,956	43,280

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[1] 1.4 employees/family

[2] 3.62 persons per family anticipated for projected employees. Not typical of present size.

[3] For present population levels see p. 53-55.

It is apparent that the anticipated non-Indian population increase will be concentrated off the reservation where the facilities for schools, education, and residences will be most readily available.

It is also apparent that these anticipations are based on effective land use planning within the reservation, the importance of which is discussed subsequently in the chapter on mitigating measures which can lessen impacts.

The time period necessary for either of the two levels of development to be attained is dependent on many factors not yet determined. However, it is expected that the low level of development will be reached within less than 10 years and that the high level of development would take substantially longer, perhaps as long as 20 to 25 years. The employment and income-producing capabilities and the increased population resulting from these two assumed levels of development are bound to have a very significant impact on the Crow Reservation which will be felt for a much longer period of time.

The Impact of Tribal Revenue

As previously indicated, it is anticipated that approximately $8,000,000 in coal royalties will be paid to the Crow Tribe at the low level of development and about $36,000,000 annually at the high level. Four basic alternatives may be considered for the use of these revenues: (1) the establishment of a trust fund for which the tribe designates, or acts, as a fiduciary for investment of revenues for the future income of its members; (2) the development of socio-economic programs for tribal members; (3) the establishment of a venture capital fund for tribal or individual Indian enterprises; and (4) distribution as per capita payment. Each of these alternatives implies specific administrative structures and costs.

All of these alternatives have considerable merit, and it is logical to assume that all will be given serious consideration. The first three alternatives have the capability of insuring, to some degree, future income to the tribe and its members while the last can substantially raise the annual short-run income for the individual Indians and their families.

Some of the options that may be applicable with the first three alternatives include: (1) the purchase of secure investments; (2) the acquisition of lands to minimize alienation and expand the resource base; (3) the development of loan programs for tribal and individual Indian enterprise; and (4) the support of social programs in health, education, housing, and special cultural development.

Since short-run desires and motivations are always in sharp focus, it is also reasonable to expect considerable pressure from the tribal membership, both resident and off-reservation, to distribute a significant portion in per capita payments.

Assuming two different distribution patterns (40 percent and 60 percent of the total royalty revenues as per capita payment) to be the probable levels of distribution, this would have some short- and long-run implications for present and future tribal incomes at both levels of development.

As shown in Table 19, at the low level of development with 40 percent of the royalty revenues distributed as per capita payments, $3,200,000 would be available for per capita and $4,800,000 for social programs and investments. With 60 percent of the royalties distributed as per capita payment, the converse would be true, with $4,800,000 available for per capita and $3,200,000 for investment and social programs.

Table 19 Possible Royalty Revenue Distributions

Level of Per Capita Distribution	Per Capita Distribution million dollars	Amounts for Investment and Socio-Economic Programs million dollars
Low Level		
40%	3.2	4.8
60%	4.8	3.2
High Level		
40%	14.4	21.6
60%	21.6	14.4

At the higher level of development, the amount available for both per capita and investment purposes would be substantially higher than that at the lower level. As illustrated in Table 19, the amount available for investment and social programs, as well as that for per capita payment, would be very substantial with either pattern of distribution.

The impact of per capita payments on the incomes of Crow members is illustrated in Table 20, which compares the 40- and 60-percent patterns of distribution to the family and individuals at the high and low level of development.

Table 20 Per Capita Payment[1]

	40 percent		60 percent	
	Annual	Monthly	Annual	Monthly
Low Level of Development				
Individual	$568	$47	$852	$71
Family[2]	$2,056	$171	$3,084	$257
High Level of Development				
Individual	$2,558	$213	$3,837	$320
Family	$9,259	$771	$13,890	$1,158

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[1] Assumes total Tribal enrollment of 5,629 (resident and non-resident).

[2] 3.62 persons/family anticipated in the projected employees. Not typical of present family size.

As can be seen in Table 20, with a 40 percent distribution of royalties from the low level of coal development, the individual would receive a per capita annual payment of $568, and based on 3.62[1/] persons per family, the average family would receive $2,056. This would be the equivalent of $47 per month for the individual or $171 per month for each family. The payment from the high level of development is approximately four times that of the lower level. This would mean a per capita payment to each individual Crow member of $2,558 annually ($213/month), or an average family would receive $9,259 annually or $771 a month.

With the 60 percent pattern of per capita distribution of royalties from the low level of development, the individual Crow Tribal member would receive an annual per capita payment of $852 ($71/month), and the average family would receive approximately $3,084 ($257/month). At the higher level of development, a more than fourfold increase would again result, the per capita payment being $3,837 per year ($320/month) and the family payment $13,890 a year ($1,158/month).

The foregoing provides a picture of the income impact which the tribe and every member may expect at the two levels of development. The effect of these increased incomes and availability of funds on future Indian lifestyle will indeed be significant. The income distribution plans will be extremely important decisions for the tribal leaders to make.

[1/] It was assumed that over time the Indian families of those employed in coal development would approximate the family size of similar non-Indian families as birth rates decline and the nuclear family becomes more dominant.

The Impact on Intercultural Relationships

It is not anticipated that there will be any severe stress on intercultural relations at the low level of coal development since no major change in the social mix is expected.

At the high level of development, severe pressures on present intercultural relationships are likely to occur. No doubt, additional law enforcement personnel will be necessary with the influx of people associated with large-scale development. It is estimated that one police officer is needed for each 1,000 people. This would mean an additional 40 to 50 officers for the entire area, including five or six more officers on the reservation to service the expanding population. To serve a more urban community, an updated judicial system, which would include juvenile codes, will be needed to control and guide the changing society accompanying large-scale coal development.

As has been indicated, the Indian and non-Indian have accommodated to the lifestyles of each other over the past decades. These accommodations, however, are based on a largely rural society, and as the area becomes more urbanized with the influx of workers and their families, they will be severely tested if adaptations are not made. That the lifestyle of present residents, both Indian and non-Indian, will be changed is a totally predictable fact. Whether or not this will result in environmental or cultural decline will depend to a large extent on how effectively controls are developed and utilized.

If a large influx of outsiders were to move on to the reservation, both the Indians and non-Indians now resident would become minorities within their own environs. The political picture would change considerably, with a definite possibility that political dominance would shift.

The present lifestyle, the cultural values, and the Crow language of the Indians will be diluted to some extent with the influx of large numbers of non-Indians. Although out of this could come a richer cultural heritage, it will no doubt be combined into new forms. It will only be by maintaining political influence and developing an effective planning process, coupled with effective controls, that the traditions and heritage for both the Indian and non-Indian can be preserved.

A potentially serious and complicated problem can be anticipated with respect to the valley areas along the Little Bighorn River and its tributaries. This is presently the most heavily settled area on the reservation, and it is here that the most intense population pressures can be expected once construction and development of the mining operation commences. It is among the most desirable portions of the reservation for permanent settlement and is the most convenient to the projected development. As is shown in Map 6 (page 93), a considerable portion of the land area in these valleys is fee land which is neither Indian-owned nor under the trust responsibility of the Federal Government. In some areas fee land constitutes more than 50 percent of the total.

The town of Lodge Grass is presently included in the land use planning efforts of the Big Horn County Planning Board. They are currently considering the adoption of a sub-division ordinance but no place other than Hardin has adopted either a sub-division or a zoning ordinance including those communities under the clear jurisdiction of the Crow Tribe.

Consequently, in the absence of some form of controls by the State or county, undesirable forms of residential and commercial development would occur within the reservation along the Little Bighorn Valley unless the Crow Tribe exercises control. For instance, unless there are such controls during the construction stages, a proliferation of trailer parks and mobile homes with inadequate sewage treatment facilities can reasonably be anticipated. Such a situation would render any attempt by the Indians toward orderly residential and commercial development in these valleys ineffective.

This potential situation points up an urgent need for accommodation between tribal, State, and county authorities aimed at joint, coordinated, comprehensive planning and land use controls. Delays caused by jurisdictional disputes or uncertainties could delay or prevent the timely undertaking of planning and the imposition of effective controls on land use, to the detriment of all concerned.

Anticipated Settlement Patterns

Developing settlement patterns to accommodate the projected residential, shopping, commercial and public service facilities is a pressing concern. If the communities within the Crow Reservation are to develop and expand in an orderly and beneficial way, a good deal of planning must be done and effective controls developed. It is assumed that the Crow Tribe will place some definite restriction on the development of residential and commercial areas for non-Crows. Based on this assumption and the availability of housing, schools, and other facilities needed, it is further assumed that the large majority of non-Crow families will live outside the reservation, thereby minimizing the disruptive impact.

At the low level of development, it is anticipated that the majority of both Indian and non-Indian employees would be taken from the present ranks of the unemployed and under-employed presently living in Big Horn County. Most of the migrant construction and operational workers with critical skills are expected to live outside the reservation. Therefore, there would be no significant increase in the number of residents on the reservation attributable to coal development.

At the higher level of development, the impact will be felt much more keenly, unless very stringent measures are implemented to restrict non-Crow residential development. With effective land use control, it is reasonable to assume that approximately 19 percent of the non-Crow families moving into the area will live in Hardin, while about 48 percent will live in the Sheridan, Wyoming, area and, that approximately 19 percent will live in non-Indian communities along the Yellowstone River. Assuming these controls, only about 14 percent of the non-Crows are expected to live on the reservation.

On the other hand, it is anticipated that most of the Crow employees and their families will settle on the reservation, with only about 12 percent in Hardin, six percent in the Sheridan area, and three percent in communities along the Yellowstone River. Assuming adequate land use planning and controls, this indicates that ethnic identity can and will be maintained.

At the high level of development, the pressure for residential facilities will become acute. Development activity on the Crow Reservation and the Ceded Area will mean an expansion in population of over 45,000 or nearly 13,000 families. Based on this projected pattern, it appears that Hardin will be called upon to provide for 2,175 (including 71 Indian) new families. The Sheridan area will be called upon to provide for nearly 5,700 families, while the communities along the Yellowstone will absorb approximately 2,900 new employees and their families.

In addition to the anticipated 465 Crow families who will likely settle on the reservation, there are very likely to be nearly 1,330 new non-Crow families who will settle along the Little Bighorn River in or near the small towns of Lodge Grass and Wyola, as well as in a scattered pattern along the entire length of the valley.

Projected Service Needs

Public assistance requirements and levels for needy families may decline slightly as employment from coal development increases. However, after the peak of construction activities is reached, the amount of assistance required through welfare and unemployment compensation is very likely to increase markedly. Although the percentage of the population receiving assistance may decrease as the level of development rises, the actual number receiving may well increase substantially, particularly as employment levels vary seasonally and as certain phases of construction near completion.

One possible result may be a sharp decline in Indian dependency on public assistance due to substantial per capita payment from the tribal funds derived from royalties, as well as from increased employment opportunities. If substantial per capita payments are made to the individual Crow Indians on a continued program basis, this could result in a stable income which would largely replace existing dependency on welfare.

Educational requirements will increase with the influx of people and will necessitate the addition of more teachers and classrooms since there is already some overcrowding in present facilities. Since at the low level of development a substantial increase in the number of families in the area is not anticipated, the impact on school needs will be modest, requiring little if any increase in number of teachers or in facilities directly attributable to coal development.

However, at the high level of development, the increase in population will increase educational needs very markedly. Based on 1.2 students per family, increases in elementary enrollment directly attributable to coal development will be approximately 8,154 students, approximately 383 of them Indian. Comparable increases in secondary school enrollments are projected, with a total of 1,900 new students, of which 324 will be Indian.

If there is to be one teacher in a classroom for every 25 students, this will require the addition of approximately 603 new classrooms and more teachers, 29 of them for the increased Indian enrollment.

Because public school districts extend over reservation boundaries, the areas which will feel the greatest amount of impact are difficult to ascertain and will be dependent upon the settlement pattern to a very large degree. It is anticipated that, at the high level, a very large proportion of the new enrollment will be in the Hardin and Sheridan areas. However, Lodge Grass, Wyola, and Crow Agency will need additional facilities to meet the demands of the increased enrollment within the reservation.

Housing needs in the coal development area are presently acute, with an estimated 800 new Indian housing units required. If these 800 are developed, they should suffice for the low level of coal development.

However, at the high level of development, another 375 to 400 houses will be needed to provide for the additional Indian families which will be resident on the reservation.

With coal development, a good deal of the housing for the initial construction and operational stages will be met with mobile homes requiring only foundation, utility hookups and street facilities. For both Indian and non-Indian, the low level of development will require only a very modest increase in the number of housing units. However, at the higher level of development, it is anticipated that over 11,000 new housing units will be needed. Again the major shortage of housing will be in the Sheridan and Hardin areas.

Health needs are expected to increase substantially only with the higher level of development. Based on a very minimal health standard of one doctor for every 1,500 people, the entire area would require approximately 43 more doctors to maintain a minimally adequate professional staff. This increased need, directly related to Crow coal development, would also require extensive increase in nursing care personnel and facilities.

The Crow Indians are presently served by the Indian Health Service facilities and personnel. Coal development would require a substantial expansion of these services, a direct result of an increased population as well as an anticipated higher level of awareness of health care benefits.

Associated Social Effects

Changes resulting from coal development will have both disruptive and stabilizing influences on the people and the social structure of the community. The desirability of the changes associated with the urbanizing society would, to a large degree, be evaluated by subjective means based largely on the biases of the interpreter. The low level of development would in itself cause relatively little social disruption since it would require practically no relocation of local people and only a moderate influx of outside employees. Of course, continuing social change is expected with or without development, and this will be accompanied by at least some socio-psychological trauma. However such change is expected to be at least somewhat evolutionary and of the type and scope with which present institutions can reasonably cope.

At the projected high level of development, greatly accelerated social change must be anticipated. The Indian culture will be put under pressure to change, and as income levels rise, other socio-psychological changes are anticipated: there will be a tendency for increasingly acute social situations such as alcoholism and emotional disturbances, as well as the breakdown of the primary social bonds of the family and traditional community.

Political influence will shift with an influx of mine and industrial workers. Unless strong measures are taken to maintain a strong Indian community, their present political viability is bound to diminish significantly. Political control of reservation affairs by the Crows will be in direct proportion to the dominance of Crow residents, both in numbers and organizational effectiveness.

Community identity and cohesiveness will be severely tested as new residents, facilities, and institutions make their influence felt. If a community is allowed to grow at a highly accelerated rate and dominant roles are shifted, the community may take on characteristics which many present and future residents may find distasteful.

Social Patterns and the Community

Social patterns involve the interaction of lives in the community, but they begin in smaller units such as the family. Coal development could affect the family in one or more of several ways.

The increased regular income could result in better housing, more adequate nutrition, children with more pride in themselves, their home and their family and, as a result, more determination to acquire a better education and be prepared for better jobs. The work habits that may be rather difficult for the older generation to accept will become a part of the lives of the younger generation. The added facilities for health, education and other services will provide additional benefits.

On the other hand, this increased income could provide a greater opportunity for alcoholism leading to socially undesireable behavior. Income from large-scale coal development could increase dependence by the Indian people on the royalty income and the trauma which would accompany the end of this income if and when mining ceases.

The Indian communities which will be most affected consist of a geographic area along the Little Big Horn River from Hardin to Wyola. If a large number of new people settled in these communities, the Indian people could become a minority in their own community, with the accompanying social and governmental implications, of which at least some would be undesirable to the Indian people. Since social values both influence and are influenced by the social patterns of a community, changes in these patterns brought about by an influx of new residents will be unacceptable to the long-time residents. This will bring about varying degrees of social stress until an accomodation of values and influence is established.

Past experience has shown that in some cases when one company provides most of the jobs in a community and pays a large percentage of its taxes, the town tends to be run by the company even though it is not a "company town" in the sense of company-owned housing and services. Some companies have used their influence to dominate the tax structure, as well as the political structure of a community. It is possible for a firm to take more out of a community through tax under-payment than it returns, although publicity over its generosity convinces communities they are net beneficiaries.

Unless definite planning and implementation procedures and programs are established which direct themselves to these issues, situations of serious social stress are likely to be common. Only programs which will minimize the detrimental impacts while maximizing accomodation to enevitable change can effectively deal with such issues.

Transportation Systems

A high level of urbanization will necessitate more highways and streets to handle the higher level of traffic. The increased traffic will likely result in greater risk of accidents and call for more traffic control measures. The higher the level of development, the greater these transportation impacts will be, and because of the high degree of mechanized movement associated with coal development the transportation impact will probably increase out of proportion to the increase in population. At the higher levels of development, many of the transportation facilities would probably be inadequate to handle the traffic.

Depending upon the level of mining activity, major changes can be expected on the road system within the entire coal bearing area. Permanent access roads into all mine sites must be built.

The mining activity also will have an impact on roads outside the immediate vicinity of the mine sites. Traffic will increase dramatically as workers commute from Hysham, Forsyth, Lodge Grass, Crow Agency, Hardin, Sheridan, and other reservation or peripheral towns. The increased traffic from people commuting to and from work; trucks servicing the mines or plants; sales and professional people traveling, as well as local farmers, ranchers, and hunters, would probably lead to paving of secondary roads to the plants or mine sites. This additional activity could lead to limited commercial developments such as gasoline stations or cafes near the mine or plant areas.

The low level of mining will need almost as many access roads and will have a much greater impact on the area on a per ton basis than the high level of production, although the high production level would cause much higher dust and noise levels and have greater impact on wildlife.

Both north and south bound rail traffic on the branch line of the Burlington Northern would no doubt increase dramatically should coal be transported through the Little Big Horn valley. This may call for extensive modernization of present facilities, including crossings. Shipment through other anticipated rail spurs would have minimal effect on the entire area after construction. This construction itself would result in considerable acreage being disturbed, with attendant reclamation needs.

Air traffic to the Hardin airport would no doubt increase dramatically, possibly calling for improvements in the strip and facilities. However, it is anticipated that the major increases in air traffic would be felt in Billings and Sheridan where significant increases over present loads could be easily handled.

Communication

The high level of development would require that communication facilities be expanded and extended. Similarly, expansions of electric, phone, television and telegraph facilities would be required. Expanded mail handling and delivery systems will be required for adequate service.

Services and Utilities

Services and utilities are essential to a pleasant and comfortable environment in any community. At the low level of development, the present service and utilities could be extended to cover the minimum needs, but as the level of development increases, the service and utilities needs will continue to increase and major changes in the service and utility facilities will have to be made. Waste treatment plants in particular will require sophisticated and expensive improvements. A service lag is likely to prevail until financing and construction of service facilities takes place.

Accidents - Probability and Risks

Much of the coal in the Crow coal resource area is near the surface and can be strip mined. In 1970, the average strip miner in the United States produced 36 tons of coal per day compared to 14 tons per day for the underground miner. Because of the physical and economic factors involved, the coal will probably be mined only by surface mines.

The accident rate for surface mining is much lower than for underground mining. The following statistics compare accident rates for underground and surface mining.

Table 21 Accidents Per Million Tons of Coal Mined
1973

Type Mining	Disabling*	Fatal
Underground	37.11	0.41
Surface	4.35	0.05

Source: Mining Enforcement and Safety Division
* Includes all lost time accidents

The accident rate for surface mining is comparable to that of similar construction industries, while underground mining has a much higher rate. As shown in Table 21, the rate of disabling accidents for underground mines was more than eight times that of strip mines, while the rate of fatal accidents for underground mines was seven times that of surface mines.

Historical and Archaeological Sites Affected

Historical sites, including such evidence of past human activities as intertribal and Indian-White battlefields, old trails, roundup camps, and old homesteads may be destroyed at the mine sites unless painstaking efforts are taken to prevent the destruction. Numerous old structures, equipment and similar artifacts are likely to be removed during mine and site preparation.

Evidence of Indian history in the coal development area prior to the Crow's coming in the 1700's is not abundant. After Crow occupation, the Wolf Mountains came to hold religious significance. Mining the face of the Wolf Mountains would permanently destroy this symbol of Crow culture.

Unless great care is taken to examine areas where earth moving is to take place, some significant archaeological sites, many of which have not yet been discovered, may be inadvertantly destroyed in the path of the draglines. These sites which may include vision-quest cairns, rock art, rock shelters, lookouts, bison traps, lithic areas, and tepee rings will then be lost to future generations.

PHYSICAL ENVIRONMENT

AIR QUALITY

Air quality will be degraded in the vicinity of the various mines and industrial plants. While the degree and significance will vary for each activity, the problems for each will be relatively similar. In other words, the dust problem from a small mine will result in somewhat the same kind of pollution as that from a larger mine; it will differ, however, in degree. The following discussion will investigate air pollution from four sources: strip mines, power generating plants, gasification plants, and liquefaction plants. Degree of pollution as related to size will be explored in each discussion.

Strip Mines

Small pockets of gas, principally methane, may escape from the coal seams, but no reference could be found indicating such gases have caused problems or pollution from strip mines in the United States or abroad. Apparently when released to the atmosphere, the quantities are so small and dilution so great that the leakage is not detected. Similarly, emissions from vehicles and equipment should prove relatively inoffensive and localized. Therefore, air pollution from gases or emissions will be minimal.

However, the same will not be true for fugitive dust which can drastically degrade air quality. Below is a list of sources which will probably be the greatest offenders:

(1) Construction equipment during the road- and rail-building phase.

(2) Loose spoil banks prior to reshaping and planting.

(3) Mining equipment--dragline, trucks, loaders, etc.

(4) Blasting.

(5) Crushing and loading. (Although most equipment in both operations will be covered, some leakage is usual in these activities.)

(6) Loss of coal fines from rail cars during transport unless cover or chemical treatment is provided.

Many of these will be point sources and therefore amendable to control as discussed in Chapter IV. In addition, the sources are low level which should result in rapid dispersion (although conversely, the local effect will be greater). Reports from the mining area at Colstrip indicate that the haul roads are the worst polluters. Moving equipment will pulverize the ground as it hauls, creating a layer of fine dust. This source should be inoffensive if the contractor is successful with required road-watering programs. If he fails, a vast quantity of fine silts and clays will be available for the wind to raise into a cloud.

To determine the effect of such a failure, and to give a notion of just how far the cloud will travel before it disperses into insignificance, the empirical relationships of D. Bruce Turner were resorted to.(24) The computations are presented in Appendix Q, and it should be emphasized that this method is only approximate. The analysis indicates that the dust cloud will travel less than one-half mile before either settling or dispersing to the point at which it becomes less of a nuisance (under 60 $\mu g/m^3$, the EPA 24-hour secondary standard; see Appendix B). The size of mine will change the amount of area from which the dust originates but not the distance traveled. The fugitive dust at the railhead and dock should travel an even shorter distance.

After completion of mining and reclamation of the land, air quality conditions should revert to much the same as they were prior to mining disturbance. This does not preclude further dust storms, however. As pointed out in Chapter II, during periods of high winds and extended dry spells, dust storms may presently occur with opacities almost as great as from the mining operation.

Power Generating Plants

Stack Exhausts - The combustion of coal or char to generate steam will produce an exhaust gas containing particulate matter (mostly fly ash), water vapor, nitrogen, oxygen, carbon dioxide, sulfur dioxide, oxides of nitrogen and certain trace elements. Emissions of hydrocarbons and carbon monoxide are normally quite low.(25) The nitrogen, oxygen, and carbon dioxide released will have little impact. (While the release of CO_2 is controversial from a theoretical standpoint and may eventually become important from a practical standpoint, the adverse impact of CO_2 from a plant such as this has not been determined). Nor will the water vapor from the stack cause much impact (although it will from the cooling towers). However, particulate matter, sulfur dioxide, and oxides of nitrogen will cause air pollution. Pollution from the trace elements will be discussed separately.

Although the basic assumptions for this study include only power generating plants utilizing waste steam (from the gasification process) and waste char (from the liquefaction process), the following discussion on air pollution will include the problems facing a coal-burning power generating plant. Thus the reader will have a conception of the range of air pollutants emitted by burning coal or char (each having different chemical makeup) in the event industrialization occurs somewhat differently than is presently assumed.

Particulate Matter - It is assumed that the coal will contain about nine percent ash by weight. Since the coal has been estimated to have a heating value of 9,000 Btu per pound, combustion will leave a residual of about ten pounds of ash per million Btu. The char will have a smaller percentage of ash, possibly six to seven pounds per million Btu.

Of the ash, about 20 percent will remain in the hopper bottom of the furnace while the remaining 80 percent will escape as fly ash. Thus about eight pounds of fly ash per million Btu will enter the stack from the coal and roughly 5.5 pounds from the char. This greatly exceeds the EPA standard of 0.10 pound per million Btu (Appendix B). Emissions at this rate would cut visibility drastically, affect respiration, and coat the land with a fine layer of dust. However, the impact would be lessened and the emissions decreased to meet standards after mitigating measures are taken. These are described in Chapter IV.

Sulfur Dioxide - The coal can be estimated to contain 0.8 percent sulfur. If the coal is assumed to have a heating value of 9,000 Btu's per pound, its sulfur content would be approximately 0.888 pounds per million Btu's. This does not hold for a generating plant burning char, since most of the sulfur is removed before the char is formed. As much as 95 percent of the sulfur from coal will be emitted as SO_2(27); this factor, coupled with the weight of oxygen added, indicates that the amount of SO_2 released will equal about 1.68 pounds per million Btu. The EPA standard for SO_2 emissions is 1.2 pounds per million Btu.

If no control is exerted, the SO_2 will be adsorbed by plant cells producing chlorosis and other damage, and eventually possible collapse. In humans and animals, the upper, and under certain conditions, lower respiratory tracts will be irritated. Reactions can also take place with water vapor, the end product being sulfurous or sulfuric acid mists, which although weak, can be extremely toxic.

As in the case of particulate matter, mitigating measures must be taken to lessen the impact and to meet EPA standards. These are described in Chapter IV.

Nitrogen Compounds - The quantities of nitrogen oxides in the plant exhaust are more difficult to quantify since they depend upon the heat of combustion. However, strict standards are maintained by EPA. These are for an emission rate of no greater than 0.7 pound per million BTU input. The maximum permissible concentration is 0.05 ppm on an annual arithmetic mean basis or 100 ug per cubic meter (assuming $1\ ug/m^3\ NO_x = .52 \times 10^{-3}$ ppm). These standards must be met by the mitigating measures described in Chapter IV. If not, photochemical smogs are possible in the area.

Trace Elements - The quantities of trace elements in the Crow coal are unknown. In addition, the tolerance of various plants and animals to many of the elements has not been thoroughly investigated. However, certain elements such as mercury and flourine are known to be very toxic in small concentrations.

The nearby Colstrip coal was assumed to average 35 ppm of flourine in the Environmental Impact Statement prepared by the State of Montana for the power plant at Colstrip.(7) The writers of that document analyzed the emission rate and concentration of flourides for their conditions and found a maximum probable concentration of 0.02 ppm in the plume as opposed to a State standard of 1.0 ppm (24 hour average). There are, as yet, no Federal standards.

Reliable measurements of mercury content in the Crow coal are not available. However, analyses of Montana coal performed by the United States Bureau of Mines indicate it can probably be classified as a low mercury coal.(29) Thus, there is reason to believe that the concentration is less than that in other parts of the country. Unfortunately, mercury emissions from coal combustion have received less attention than they should, considering that they could be suspect in mercury contamination.(30) (31)

The emission of radioactive elements was investigated in the Colstrip Impact Statement and was found to be negligible. The Crow coal should pose no more of a problem than the coal near Colstrip.

Cooling Tower Water Vapor - Water vapor from cooling towers under certain conditions may cause ground fog, but otherwise it should be of little concern. It will be necessary to construct the towers high enough and possibly to use mechanical draft fans with high air-to-water ratios to disperse the vapor before fogs can form.

Gasification Plants

The exhaust emissions produced by a gasification plant per ton of coal consumed should be less than those produced by a power generating plant. This is because most combustion in a gasification plant occurs as reactions within closed vessels in the absence of air. The volatile matter and gases are trapped, either for use in later processes or because they are too deadly to allow to escape. For example, little sulfur dioxide is formed. Instead, when the hydrogen-rich gas reacts with the fluidized coal, it also reacts with the sulfur in the coal. The result is the formation of hydrogen sulfide gas in lethal quantities. All the H_2S must be captured, and with it other byproducts of the reaction are captured such as various aromatic organic compounds, trace elements, ammonia, etc. The hydrogen sulfide is reduced to elemental sulfur; other compounds trapped can be burned (such as ammonia) while some appear in the waste water which requires a very sophisticated treatment.

In practice a slight amount of H_2S will escape through the sulfur plant vent. For example, it is anticipated that the El Paso Natural Gas Co. plant proposed for the Four Corners area of New Mexico would release about 6.6 ppm from this vent.(32) With a proper stack design, this can be decreased to well below 0.1 ppm at ground level.

Since exterior heat is required in several of the processes, not all combustion occurs within closed vessels. Therefore, there will be fly ash, sulfur dioxide, and oxides of nitrogen discharged from furnaces, boilers, etc. The types of emissions will be much the same as those from the power generating plants discussed in the previous section, and the control measures would be of the same kind. Only the quantities will vary.

The pilot plant studies for the process chosen in this report (the CO_2 Acceptor Process) did not quantify the amounts of air pollutants emitted. But the process has given indications of being considerably more efficient than the Lurgi and therefore should produce somewhat fewer pollutants per million cubic feet of gas produced. For the Lurgi process, the quantities are considerably less than for a conventional power generating plant.(33)

A recent report on the newer processes seems to confirm this claim.(34) The El Paso work referred to previously(32) indicates that the quantity of SO_2 escaping will be near 0.13 lbs./10^6 Btu while the amount of NO_x is approximately 0.26 lbs./10^6 Btu; both amounts are well within EPA requirements.

The CO_2 Acceptor Process will have an additional stack emission over and above the Lurgi's. It is from the dolomite-recalcining unit. Since char, containing less ash than coal, will be burned, particulate matter in the exhaust will be low. Oxides of nitrogen will cause a greater problem, but the controls mentioned for the burners in the section on power generating plants can be used in the recalcining operation. However, the concentration of SO_2 in the exhaust is much greater in the recalcining process than for normal coal burning. The reason for this is that the dolomite absorbs H_2S in the various prior units. While most is reclaimed, enough sulfur remains to cause SO_2 problems when the dolomite is recalcined. Scrubbers with SO_2-removal efficiencies approaching 90 percent will have to be perfected before emissions will meet EPA standards. (Manufacturers presently claim these efficiencies for their products, but to the writer's knowledge the technology has not been thoroughly tested to prove the claims.)

Liquefaction Plants

The liquefaction plant described in these pages for Complex B is in the pilot plant stage. Therefore, quantitative values for process emissions from a plant of the capacities possible for installation on the Crow Reservation are not available. However, as with the gasification plant, the coal reactors are closed vessels and most of the coal "combustion" will take place in the absence of air. A gasification unit will be required to produce the hydrogen needed. It and the coal reactor's air pollution problems will be similar to those described in the previous section under gasification plants, although on a reduced scale. Air pollution caused by the residual char used in the power plant at Complex B has been discussed in the section on Power Generating Plants.

Unfortunately, the remainder of the liquefaction plant at Complex B will emit pollutants into the air. Boilers and process heaters will require coal combustion. Also leakage at vessel and pump seals, etc., will create problems. In discussing this matter with officials of Consolidated Coal Co., it was learned that the problem will be similar to that of an oil or gasoline refinery of similar size. Thus, this section will consider the pollutants produced by a refinery.

The following data are mostly from material contained in Reference (35) which describes the air pollution emanating from a 100,000 barrel per day refinery. The plant proposed for Complex B would have a 200,000 barrel per day capacity.

Appendix S shows the emissions from a 100,000 barrel per day plant. The primary source of atmospheric emissions is from the catalytic cracking and regenerating units. The authors in the reference found that the particulate matter, oxides of nitrogen, carbon monoxide, and hydrocarbons were subject to control. The SO_2 emissions did not meet EPA standards. Unless controlled, the sulfur dioxide will be harmful to humans, animals, and plant life in the vicinity of the refinery.

Other emissions are ammonia, aldehydes, organic acids, and odor producing aerosols such as mercaptans. These emissions are all so low that they would not affect health or public welfare. However, their nuisance value may be great unless controlled by air stripping and recirculation to furnaces or boilers.

As in the case of the gasification plant, the hydrogen sulfide must be trapped and sent to a sulfur recovery unit.

In summary, the foregoing analysis indicates that coal- or char-burning energy plants on the Crow Reservation can individually meet present air quality standards in most respects. However, whether they can meet standards collectively is an open question. The plants at each of the separate mining locations would be located sufficiently far apart (no less than 15 miles) that they will not create an additive effect on each other. However, the three separate plants contained in Complex B could well degrade air quality below standards when operating together. The predicament with SO_2 was alluded to in the previous section. In addition, the ground level concentration of NO_x may exceed permissible amounts under certain wind conditions. Hopefully, the state of the art will have progressed to a point where pollution control technology will cut degradation to a minimum. When a specific plan is presented, careful attention should be paid to the impact statement analysis of this particular problem.

But even if detailed analysis indicates that the plants meet current air quality standards, whether this will eliminate all impacts is questionable. Pine trees, for example, can be injured by continual exposure to such chemicals as sulfur dioxide in the presence of moisture. Table 22 taken from Reference(36) illustrates the effects of three of the pollutants possible in the plant emissions. In addition, fluoride is particularly injurious, since it will eventually accumulate in cell tissue. References (37) and (38) describe the toxic effects of continual exposure to small quantities of various pollutants. They indicate that plants and animals will sustain damage in a variety of ways and degrees even when standards are met. A bibliography of such literature is contained in References (36) and (39). The wind rose shown in Chapter II indicates that two quadrants (SE and NW) will bear the brunt of any damage which may occur. However, the topographic features of each location will create for each its own wind rose. Therefore, careful siting is essential along with continual monitoring and periodic analyses of the animal and plant life to minimize adverse effects.

Table 22 Data on Which Some Air Quality Standards are Based

Concentration in ppm by volume	Effect	Species
Hydrogen Sulfide (VDI 2107--April 1960)		
700	Quickly fatal	Man
400-700	Dangerous (30 minutes or less)	Man
170-300	Intense local irritation	Man
100-300	Spontaneous Injury	Animals
70-150	Slight symptoms	Man
20- 30	Strongly perceptible odor	Man
1.5	Toxic limit	Plants
0.3	Definitely perceptible odor	Man
0.1	Slightly perceptible odor	Man
0.025	Olfactory threshold	Man
Nitrous Oxides (VDI 2105--May 1960)		
40- 80	Pulmonary edema	Animals
10- 20	Methemoglobin formation	Man
1- 2	Minor irritation	Man
0.1	Olfactory threshold	Man
Sulfur Dioxide (VDI 2108--November 1961)		
100	Strong irritation	Man
10- 50	Irritation	Man
1- 10	Contradictory findings	Man
1- 2	Damage	Man
0.3-1.0	Perception threshold	Man
0.15	Tolerance limit	Plants

A recent court ruling tentatively indicates that air quality cannot be diminished significantly from its present state. Obviously, the emission of several hundred pounds per hour of various pollutants which do not now escape into the atmosphere constitutes a decrease in air quality. The degree of dilution in the air flow and the resulting concentration might determine its "significance," although that term has not yet been defined. Depending upon the interpretation of this ruling, or if the standards are tightened without a corresponding improvement in technology, these industrial plants might not be feasible.

Noise

The natural quiet of the Crow coal resource area will end in the vicinity of the mines and industrial plants. Noise from traffic to and from the area will increase many-fold at the high level of development. Even for low-level development, it will become noticeable over the eastern part of the reservation. Noise problems at each type of development will be discussed separately.

Strip Mines - Noise levels in the immediate area of the mines will rise drastically. The din from the mining and loading equipment and the coal crusher will reverberate through the nearby coulees and across the adjacent ridges. However, the main effects will be felt by the workers. Sound levels in the vicinity of the crusher and other equipment will probably range from 80 to 100 decibels. (40 & 41) When blasting occurs, the level may reach 110 or more decibels. However, since the sound wave decreases in intensity with the square of the distance, one will not have to travel very far from the site before the noise levels will drop below 70 decibels. Assuming a a six-decibel decrease in sound pressure level with each doubling of the distance from the source, (40) the average intensity one-half mile away would be down to 40 or 50 decibels except during blasting. Of course, this will vary with wind direction, barometric pressure, humidity, and obstructions such as trees and topographic features.

The effect on livestock and other animals is questionable. Once relocated, they may be far enough from the mine that the background level of equipment noise will be reasonably low.

Deer have been sighted browsing within one quarter mile of the site where Westmoreland Resources is strip-mining coal north of the reservation boundary.

As for the blasting, a consulting research firm indicates that it will have little effect. To quote from the report:

> Cattle have been reported to graze with apparent unconcern within one-quarter mile of the coal pits at Big Sky Mine (near Colstrip, Montana) where blasting for coal removal is regularly undertaken. The stress effect on big game is not completely known at this time, but attempts to use exploding noise to scare mule deer in Alberta produced the same result as for cattle. After initial "startle" effect, the noise was subsequently ignored.

The validity of this as a practical conclusion is somewhat controversial.

Power Generating Plants - Plants of this type have numerous noise producing mechanical units. Particularly loud are the steam generating turbines and compressors. Their noise level could easily exceed 90 decibels. Fortunately, this equipment will be enclosed within the main generating building and except for a faint hum, the noise should be imperceptible beyond the boundaries of the site.

The hum from the transformers (about 70 to 75 dB) will seem considerably louder, but because of the rapid decrease in intensity with distance, it will reach an acceptable level (below 50 decibels) a quarter of a mile from the area.

The greatest noise will be from the cooling towers, which will emit a constant roar that will be heard for some distance. The State of Montana investigated the problem at the plant under construction at Colstrip and found that the value of 50 dB was not achieved until the listener retreated to a point nearly a mile away.(7)

Gasification and Liquefaction Plants - A literature search did not reveal the extent of noise emanating from either of these types of plants. However, by reviewing the units contained in the plants, such as various reactor vessels, compressors, pumps, etc., and studying industrial plants containing similar types of units, an idea of the noise level can be obtained. As mentioned under Air Pollution, oil refineries contain many of the operations that will exist in coal conversion plants.

The noise level within a refinery production area may often approach 100 dB.(35) Table 23, taken from this reference, indicates frequency ranges and decibel readings in the immediate vicinity of the units. Again, however, because of the drop in noise level with distance, the readings will be below 50 dB, at a distance of a mile from the plant.

Table 23 Refinery Equipment Noise Characteristics

Equipment	Frequency Ranges, Cycles per Second	Sound Level at 3 ft. (dBA)
Air Fin Fan Coolers	250-2,000	87- 94
Blowers - Centrifugal	High	100
Blowers - Rotary	Broad Band	94
Compressors - Centrifugal	550-4,000	120
Compressors - Gas Reciprocating	31-125	100
Cooling Towers - Water Pumps	500-2,000	101
Electrical Motors -		
200 h.p.	250-4,000	111
20 and 30 h.p.	250-4,000	90
Furnaces	125-4,000	95-110
Gas Engines	Low	98
Gear Boxes	500-4,000 (Discrete)	87-115
Piping	65-5,000	90- 96
Steam Boilers	150-600	88-100
Steam Leaks	500-4,000	87-118
Turbines - Gas	63-4,000	96-108
Turbines - Steam	125-4,000	91-103
Valves		108
Vents		100
Whistles		106-112 1/

1/ At distance of 10 feet.

Traffic - New roads will be constructed into all areas of industrial development and increase traffic many-fold. The result will be ribbons of noise extending from the mines to the industrial and population centers with decibel readings ranging from 50 to 100 dB (the latter from heavy trucks). Any conveyor belts constructed from mine to plant would add a clatter, and trainloads of coal or other products and supplies will rumble through the area.

In short, under maximum development, the Crow Reservation will lose much of its present serenity, with some areas resembling the clamorous eastern industrial centers. Under minimum development, noise levels in general will not be much greater than they are today, except in the vicinity of the mines.

Ground Shock

Ground shock or motion is associated with blasting of overburden material in strip mining operations. The amount of transmission of ground shock due to blasting is a function of the distance from the blasting area, the number and size of the charges exploded, and the competency of the overburden rock being blasted. In general, only the minimum amount of explosive required to adequately disturb the coal overburden for recovery by earth moving equipment is utilized due to the economics involved in mining operations. This results in rapidly diminishing ground motion effects within short distances of blasting areas. This subdued effect, in conjunction with the sparse population of the Crow coal resource area, should mean little or no property damage or inconvenience to private property adjacent to strip mining operations.

Topography - The topography of the land will be radically altered by mining operations. It will be significantly altered by a change in the elevation of the land surface, a change which will vary with differences in the thickness of the coal layers and interburdens removed. It will also be affected by the placement of materials for reclamation purposes. Associated erosion can also cause new elevations and land forms.

These changes in elevation and slope will likely create areas of local sharp relief and flattened slopes. Strip mining will also change drainage patterns as well as the size, shape and position of topographic features. Construction of roads, rail lines, plants and reservoirs will also alter the land surface significantly wherever they occur.

Removal of coal seams will cause a general lowering of topography in the mined areas. The thickness of the coal seams projected to be removed in the Northern Reservation Mine is 10 feet; the Southern Reservation Mine is 40 feet and in the Ceded Area Mine is 50 feet. This indicates that an overall subsidence of the area mined in the acreages and areas described below which will be partly compensated by the "fluffing effect" of some of the replaced overburden.

Land Resource

Acres Disturbed - One can only speculate as to how much land will finally be disturbed. For the low-level development assumed in these pages, it is estimated that at the Northern Reservation Mine, 695 Acres will be disturbed during the first year, with about 330 acres mined each year thereafter for a total of 30 years. Thus, eventually, 10,265 acres will have been disturbed at this site.

The Southern Reservation Mine at this level of development would disrupt about 2,680 additional acres during its lifetime, and in the Ceded Area, the Southeast Ceded Area Mine will affect 6,320 acres during its lifetime.

The total disrupted land, or that needing reclamation at the low-level development, would be 17,135 acres. Of this acreage, 1,095 acres would be out of production for plant facilities during the life of the projects. As for the rest, assuming one year for mining and three years before the reclaimed land could tolerate even minimal grazing, an additional 2,140 acres would be unusable at any given time.

Under the high-level development plan, this land, plus considerably more would be out of production for extended periods of time. Complex A will have a mine disturbing 500 acres annually for 30 years, plus 800 more for plant and spoil bank. An additional 900 acres might be needed for the gasification plant and a small generating plant, and an office complex and access roads of 200 more acres might be developed. The total of these land areas amounts to 2,400 acres disturbed during the first year, while over the life of the project 16,900 acres will be disrupted. At Complex A, using the same assumptions as those used for the Northern Reservation Mine, 1,900 acres will be out of production for the life of the project and an additional 2,000 acres unusable at any given time.

For lack of detailed information, it is assumed Complex B will cause the same level of disruption as Complex A. Complex C will use 600 acres for the gas and power plant and 100 acres for office and access roads, for a total of 700 acres throughout the life of the project.

Table 24 summarizes land disruption at the high and low levels.

Table 24 Acreage Disturbed Over Life of Project

	First Year of Total Operation	Maximum At Any Given Time Thereafter	Total Land Disturbed
Ceded Area:			
Southeast Mine	520	1,120	6,320
Complex C Plant	700	700	700
Mine No. 2	575	940	4,190
Reservation Area:			
Northern Mine	695	1,685	10,265
Southern Mine	360	600	2,680
Complex A	2,400	3,900	16,900
Complex B	2,400	3,900	16,000
Total	7,650	12,845	57,955

If all development were to take place on the coal tracts along the eastern side of the Crow Reservation, approximately 3.2 percent of the available land will be out of production at a given time and eventually 13.7 percent will have been disturbed. This may be unrealistic, however, since the industrial companies may wish to locate their plants closer to Interstate 90 and the Sheridan spur of the Burlington Northern.

An additional land area will be developed that is considered too nebulous even to speculate on at this time. That area would be the land needed at Lodge Grass, Wyola, Hardin, Sheridan, and any other location deemed by the workers as a suitable place to establish homes. Exactly which village or town is picked by many will depend upon the community foresight and zoning. A town can do much to make itself a desirable place to live or can discourage immigration, depending on the policies and planning of each governmental body.

Effect on Land Use - All leases issued will require that the company carry out an ongoing reclamation program. At the low level of mining 3,405 acres will be out of production at a given time, while at the high level 12,845 acres will be unusable.[1/]

Since the livestock carrying capacity varies between 2.3 and 3.2, averaging 2.7 acres per AUM in the coal area, the loss in annual income from grazing would vary between $5,990 and $22,598 at the low and high levels of coal development respectively. This is calculated by assuming a $5.00 annual rental rate per AUM. Loss of annual income from cropland, assuming $12.50 per acre, would vary between $2,125 and $8,025 respectively at the two levels.

A more serious problem will occur because of the location of the proposed mining. A large proportion of the strippable coal lies in the valleys of Youngs, Little Youngs, Tanner and Squirrel Creeks where much of the stock water and feed base is. It must be anticipated that a significant portion of the disturbed land will be of the latter type.

The toppgraphy in Townships 5 and 6 S. is rougher and steeper than that of any of the other areas that might be proposed for mining on the Crow Reservation, and here the extraction of coal may be possible only through the use of contour strip mining techniques, which will be allowed only if it meets the terms and objectives of the lease and mining plan relative to coal utilization and reclamation.

[1/] 5 percent is estimated to be in cropland and 95 percent in rangeland.

Portions of the mountains area are quite scenic and could be used advantageously for recreation. A further discussion of this impact is contained in the sections on Esthetics and Recreation.

Effects on Soil

It is inevitable that the nature of the restored soil on reclaimed areas will be greatly changed. The original soil profile will be destroyed and a new cycle of soil profile development and plant succession will proceed at a very slow pace. There will be changes which, at least in some cases, will lower the water-holding capacity, increase the soil density, increase the slope gradient, lower the water table, increase toxic chemicals in the plant zone and adversely affect other soil characteristics. On the other hand, there will also be cases where soil disturbance may have beneficial effects on these characteristics such as replacing a saline surface with more productive soil or breaking up hard sandstone so roots can penetrate.

Surface mining activities would have a significant effect on various forms of internal soil life. These organisms including not only burrowing mammals, insects, nematodes, and earthworms, but especially the micro-organisms such as fungi and bacteria concentrated in the surface or a horizon.

Until a plant cover is established , the soil material would be subject to erosion, and the sandy areas in the northern tracts would be susceptible to both wind and water erosion. The magnitude of these impacts would be directly dependent on the land reclamation methods and practices.

Effect on Vegetation

The impact of coal mining on the vegetation of the area will be of two kinds: the effect on the mined and otherwise disturbed area, and the effect on the surrounding area.

Coal mining activities will completely destroy all the vegetation on the area from which the overburden material is removed, as well as where the overburden material from the first cut is laid. The construction of such features as haul roads, a railroad loop, coal loading facilities and other structures will destroy additional vegetation.

Any strip mining operation will be followed by land-forming to grade and slope specifications, after which stockpiled topsoil or other good quality soil material will be spread. The eventual effect on revegetation will depend on how the overburden material is laid, on the kinds of plants remaining on the adjacent unmined areas and on the kinds of seeds or propagules they are able to produce.

In bare areas, various pioneer plants will invade. In this part of Montana these invading species include annual bromes and fescues, many other annuals, Kentucky bluegrass, Canada thistle, leafy euphorbia (spurge), Russian centaurea (knapweed), rabbitbrushes, poplars, willows, ponderosa pine, pricklypears, and many others. Some of the species coded Iv or U in Appendix F can be expected. Typically these plants are not tolerant of shade and have seeds or propagules that are carried by the wind or stick to the fur of animals. Many are weeds.

On north-facing slopes, in places where the mineral soil is exposed and vegetative competition is low, the pioneer plants include ponderosa pine.

Most pioneer plants are not normally permanent components of the vegetation but gradually give way, in a series of successional stages, to various perennials that may or may not be dependent on a good exposure to light. Eventually, after many years or decades, the vegetation may become similar to that which originally inhabited this kind of site. Such a final stable plant community is in excellent balance with its environment and is usually called "climax vegetation."

Adjacent to, but outside, the mined area the vegetation will not be destroyed except locally, but a number of detrimental effects can be expected.

Some dust from the mining activities is likely, even with effective sprinkling, and it will fall on the upper surfaces of plant leaves. It may reduce transpiration through the stomata on the upper leaf surfaces (resulting in less water use) and will reduce photosynthesis by reducing the amount of light.

If the dust is from material high in sodium or other harmful chemicals, the effect of the chemicals would become visible when rain washes the material from the leaves. The soil would then receive some detrimental effect from the harmful chemical.

Effect on Timber

In those limited areas of commercial forest which are disrupted, the impact on timber harvesting will be long-lasting and perhaps permanent. Most of the northern and southern portions of the coal resource area contain little commercial forest land. Though many draws have ponderosa pine and juniper, the trees are generally short and widely spaced and the forest stands are widely separated. With the exception of the northwest part of the Shell lease, the major portions of the forest lands in its lease and in Peabody permit area are generally very marginal and are not considered in the Crow Reservation forest harvest schedule.

However, the central mountainous portion of the coal resource area is in the heart of the Wolf Mountain timber land. These timber reserves contain three quarters of the 3 million board feet cut on the Crow Reservation. See Appendix U for forest acreage disturbed by coal mining and Appendix V for value of timber which could possibly be destroyed.

Active strip mining will in some cases be incompatible with other surface uses. Through careful rehabilitation most surface vegetation can be returned to an income-producing state within a few years after the soil and vegetative cover are stabilized. Forest land lost to strip mining cannot be so easily reclaimed. Sawlog production requires a growing period of approximately 80-100 years, so several generations will pass before the mined forest lands, if reclaimable, will be capable of generating any forest revenues. It is even doubtful that some mined areas will be capable of restoration. If forest reclamation is successful, it will take approximately 40 years for the reclaimed area to achieve forest characteristics.

Aspect has a great effect on the forest environment in the Wolf Mountains. The conditions on south slopes are too severe for forest communities to become established. Consequently, the cooler, moister north slopes are forested, while the hotter, drier south aspects are in grass. The difference between east and west slopes is frequently influenced by other environmental factors. If, in the process of strip mining and rehabilitation, the land form is substantially flattened, forest communties may not be able to become established. If leveling occurs on a large enough scale, a micro-climate change may occur, as frequently happens on large clear cuts and burned-over forest lands. Such minor climatic changes have hampered efforts for reforestation on many projects throughout the United States.

In some cases, the removal of part of the forest cover through harvest in ponderosa pine stands will permit some increase in forage production as well as stimulating growth of residual timber by decreasing competition which indicates that range oriented reclamation objectives may be the more practical and therefore utilized. Regeneration in this timber type normally is based upon natural replacement, with the residual stand providing the source of seed.

Effect on Fish and Wildlife

The effects on wildlife fall into three main categories: the destruction of habitat, destruction of wildlife, and disturbance to wildlife-all three involving changes in the numbers and composition of animal life.

When strip mining takes place in an area, the wildlife is severely disturbed by noise, human activities, and various physical development. Birds and big game animals are mobile and can move out; but the smaller animals like insects, snakes, mice, prairiedogs, and the endangered black-footed ferret are unable to escape and are destroyed along with entire blocks of their habitat, including food sources, shelter, and other life requirements. When the mobile forms of wildlife move into new areas, they may crowd out individuals already there.

The degree of the impact on wildlife would accelerate with the rate and amount of habitat destruction and disturbance. Mining operations conducted at a moderate level would have an effect on a relatively small area of habitat and few wildlife numbers, while operations conducted at higher levels would obviously affect more habitat and wildlife. However, as the areas affected rapidly increase in size, approaching the 12,845 acres disturbed and under reclamation at the high level, the impact on wildlife will become more lasting as well as larger in scale. The influence of the operation will spread deeper into the surrounding lands and produce an impact on wildlife that increases at a greater rate than that of the mining operation.

The mining activity and disturbed acreage could produce adverse impacts such as alteration of migration routes; disturbance to calving areas, nesting areas, grouse booming grounds; destruction of wintering areas for big game; and others that could have profound effects on wildlife populations.

The impacts on fishery resources will depend on where mining actually takes place (i.e. in the drainage bottoms or on hilltops), the type of mining and reclamation rules required by the Crow Tribe and the State of Montana, the enforcement of these rules, and the success of reclamation efforts.

If the stream channels are not mined, surface waters are not degraded, and flows are not significantly reduced, there will be little effect on stream fishery resources regardless of the level of mining development.

If stream channels are mined, effects of the mining will be apparent many miles below the lease areas. Likewise, if silt and other sediment are not adequately controlled and toxic materials not contained in mined areas, similar effects will accrue. Any reductions in streamflows will adversely impact fish populations as well, both through aggravation of sediment problems and directly through reduced habitat. Ultimately, good fishing streams such as the Tongue and Little Bighorn Rivers would be adversely affected.

Probably the greatest threat to fishery resources from strip mining in the area is the potential of silt and other sediment entering the streams. The effects of sediment on aquatic flora and fauna vary with the concentrations of pollutants, and with species affected. Fine silt often stays in suspension, while larger particles settle, blanketing the stream bottom and smothering desirable aquatic life, including fish eggs. The resulting turbidity and sediment can reduce light transmittance, alter temperature gradients, absorb organic materials and other substances, and ultimately result in deposition farther downstream. The sediments and suspended matter could build up in small local streams in the mining area and be flushed downstream into better fishing waters during high flow periods.

Stock ponds below mining activities that contain fish will be adversely affected if silt and other sediment enter or if inflows are reduced. Deposition of sediment results in less food production, in destruction of cover, in less water space for fish, and in higher water temperatures. Continued deposition may result in the pond's becoming too shallow to overwinter fish. Through a variety of processes, inadequate water inflow will result in lethal conditions.

Esthetics

Esthetics may be described as those elements of a scene, viewpoint, perception or environment which contribute an artistic effect, influence or appeal. Esthetic quality is in the eye of the beholder and is therefore highly subject to different interpretations.

Esthetics may be described as visual resources made up of texture, lines, color, land forms and intrusions. Texture which consists of a particular vegetative pattern in the natural state will be changed by the different cover that will be in the cuts, fill, and other use areas. The absence of vegetation, the presence of invader plants, and the new species used in reclamation will also contribute to this change in texture.

Shaping or carving of the land by the excavations and the development of railroads, and power lines may create unnatural lines often conflicting with the natural lines of cliffs, hill and rivers. Red clinker or other contrasting material used on roads and rail beds may not blend well with the browns, grey, and greens of natural vegetation. Power line supports which are painted silver may reflec light and may be in stark contrast to the natural surroundings.

The most significant change of all will probably be the construction and location of multihued buildings, equipment, houses, and mobile homes. The operation of mining also changes the altitude and the slopes of the land, tending to create more rounded and gentler slopes while eliminating abrupt changes such as cliffs and sharp breaks.

With proper reclamation, landscaping and beautification efforts, the esthetic change may be largely a question of perception. To some people the changes brought by mining may enhance the quality, while for others the natural landscape is far more pleasing from an esthetic standpoint.

The mining operations involved in the low level of production are not expected to greatly change the esthetic qualities of the landscape, for the changes will not be obvious, and will be confined to small areas. Those most likely to resent the esthetic change at the low level of development are the landowners, ranchers, and other residents of the area.

At the high level of production, the cumulative impact of thousands of new people and the construction of the facilities associated with coal development may cause a definite change in the esthetic quality of the landscapes of the Crow coal resource area. Here the present natural state will, in the location of maximum development, be irreversibly and irretrievably committed to a change from the quiet rural setting, with its wide open spaces and basically uninhabited countryside, to an area of high activity and highly industrial character.

Recreation

Recreation includes those activities or those things which people feel contribute to their physical and psychological well-being.

Recreational use of the coal resource area is presently severely limited due to the Crow Tribal ban on nonmember hunting and fishing on trust land, and the posting by surface owners of fee land on the reservation as well as nearly all of the Ceded Area. The lack of good, all weather roads also isolates much of the land with maximum recreational potential. Most of the recreational use is by tribal members and other local residents. If the restrictive aspects of present use are retained by the tribe and the landowners, the low level of coal production will probably increase recreational use very slightly. The main difference will probably be the influx of sightseers and others interested in observing mining operations. It is anticipated that this use will make no appreciable impact on the environment or change the present use on the vast majority of the land.

At the high level of coal development, the major impact on recreational use will result from: (1) loss of land base, (2) increased population within the study area, (3) change in water use and (4) increased industrial and municipal consumption of water. The reduction in the recreational land base, although not significant when compared to the total land base, may be extremely important in terms of the area available for recreational use. An increase in population and recreational use levels almost invariably leads to closing and posting of private lands normally available for recreational uses. This further reduces the recreational land base.

The nearest public recreational area, The Big Horn Canyon Recreational Area, where fishing, hiking, horseback riding, camping, nature walks, and winter sports are available, will experience greater pressure, and probable overcrowding brought about by the increase in population at the high level of coal development. This area has a considerable capacity for expansion and with maximum development could, no doubt, provide a larger outdoor recreational base for a good portion of any conceivable increase in population.

Water Resource Depletion

Comsumptive use of water resources will occur with mining and with the operation of industrial plants that may use coal on the Crow coal resource area. The magnitude of depletion will depend on the number, size, location and types of facilities constructed. The impacts associated with these varied facilities and the volumes of water required are outlined in the following paragraphs.

Effects of proposed coal strip mining operations on the hydrologic environment will be quite pronounced. The mining operations will include removal of massive thicknesses of overburden and coal, and subsequent replacement and reclamation of the overburden. Mining may disrupt shallow aquifer systems and deplete streamflow.

Surface Water - Strip mining in the area will affect the present streamflow pattern in several ways. Where stripping pits cross stream channels, the water either will discharge into the pits or will be diverted around them. Eventually, the streamflow may cross reclaimed ground along a former channel or beneath diversion channels. Streams will tend to lose water where they cross disturbed areas unless the flow channels are lined with relatively impervious materials. The stream losses will become recharge to ground water or will be lost to evapotranspiration within the reclaimed or mined area. The streams will be depleted at least until saturation of reclaimed areas occurs, if not longer.

Where mining does not intersect a stream valley, it will still affect the surface water. Runoff that formerly originated on or passed over the mined area will encounter a disturbed surface, and if the material is permeable and unsaturated, some runoff will become recharge to ground water.

During mining, ponds may be desirable as sources of water for road maintenance, dust reduction, or irrigation of reclaimed land. To the extent that the ponds are built to intercept streamflow or surface runoff, they will reduce the amount of surface water discharged from a given area due to rainstorms or snowmelt. Some diverted water will be evaporated or transpired; the remainder will eventually become ground water recharge or will subsequently become surface runoff.

Ground Water - Where the major or total recharge area of an aquifer is removed in mining, partial to complete dewatering of the remainder of the aquifer is possible. In recharge areas that are disturbed, emplacement of permeable spoil material in hydraulic continuity with unmined aquifers and the surface may re-establish the opportunity for recharge. Mining in the discharge area or between the recharge and discharge areas will produce new opportunities for discharge and will normally result in a lowering of the water table or potentiometric surface in adjacent areas.

The alluvial aquifers in the stream valleys are recharged locally, either from precipitation, stream losses, or migration of water from adjacent bedrock. Where mining in the valleys requires that the alluvium be removed, continuity of this aquifer will be broken, and strip mine pits will become ground water discharge areas. Drainage of portions of alluvial aquifers in the valleys above mine pits will result, and portions of these aquifers below the stripping operations may be partly or completely dewatered unless the water that enters the pit re-enters the alluvium at the downstream face of the pit or through surface diversion.

A similar situation will result when mining of the bedrock aquifer occurs. However, depletion of ground water in these extensive aquifer systems will not result in the extensive dewatering that will occur in alluvial aquifer systems.

The coal-bearing strata have a gentle dip to the east or southeast on the Crow Reservation and to the northeast on the Ceded Area. Consequently, mining on the west side of the Wolf Mountains or in the Ceded Area will generally entail removal of parts of aquifers in their recharge area. Mining on the east side of the Wolf Mountains, however, will involve removal of parts of aquifers in their discharge areas or at intermediate points where they are conduits between recharge and discharge areas.

Where strip mining requires removal of clinkered ridges or mesas, potential recharge to shallow ground water from these areas will be reduced or eliminated.

Replacement of aquifers with spoil or overburden will have several effects on the occurrence and movement of ground water. In former areas of recharge, emplacement of spoils that are a mixture of rock types and fragment sizes will alter the potential rate of surface infiltration. Vertical permeability may be increased by the elimination of stratification, but lateral permeability may be simultaneously decreased by the loss of continuity of the beds. The net result may be a decrease in the amount of recharge to the aquifers.

Use of shallow ground water at the mine sites for dust control, road maintenance, irrigation of reclaimed areas, and other facilities would produce an impact on the existing ground water flow system. The water table or potentiometric surface would be lowered, and dewatering of nearby springs, wells, and stock ponds which intercept the water table could occur.

Precipitation of dissolved salts from evaporation of the ground water used on the surface for irrigation or dust control is likely unless water is applied in large enough quantities to leach the salts from the surface. The shallower ground water from alluvial deposits, principally a calcium or magnesium sulfate type, would not be especially damaging to the soil. Sodium bicarbonate type water from shallower artesian aquifers, however, would be likely to leave concentrations of sodium in the soil. This would produce deflocculation of the soil particles and formation of "alkali" spots on the surface. Water that is obtained from most deep aquifer sources would also cause alkali problems. An exception would occur with the use of an extremely deep aquifer system, such as the Madison Canyon limestone and others, which contain calcium sulfate type water.

Strip Mine Water Use - Strip mining operations will require consumptive water usage for the suppression of dust on haul roads; for domestic purposes; and for coal crushing, grading, and washing operations. Washing and cleaning of coal could also be accomplished at the point of use, or possibly eliminated altogether if the strip mined coal is relatively clean. For example, dust control at a mine producing about 5,000,000 tons of coal per year might require anywhere from 125,000 to 325,000 gallons per day during the summer months, depending on extent of haul roads.

Power Plant Water Use - Power plants using steam turbine generators utilize tremendous volumes of water for cooling purposes. If the plants are cooled by flow-through processes which utilize surface waters for the dissipation of the waste heat generated, between 400 and 600 acre-feet of water per year is required for each megawatt of power generation capacity. The water is not consumed or lost to the environment with this cooling process. However, an 11° to 17° F temperature rise, which may cause thermal pollution downstream, is imparted to the water.

With evaporative cooling systems, water is used consumptively. The consumptive water use for the type of power generation stations described in these pages is shown below:

Table 25

	Condenser Cooling	Stack-gas Scrubbing	Total Water Use AF/Yr per Megawatt
Conventional Plant (With Wet SO_2 Scrubbing)	11.0	5.3	16.3

As technology for dry tower cooling systems is perfected and costs become known, elimination of condensor cooling water requirements may become feasible. Consumptive water use by power plants with dry cooling towers and emission controls will eventually be reduced by one-half to two-thirds from that of existing plants.(43)

Coal Gasification and Liquefaction Plant Water Use - For consumptive use in evaporative tower cooling, the Complex A commercial coal gasification plant producing about 885 million cubic feet of pipeline-quality natural gas per day will require a maximum of 76,000 AF/YR of water. If a dry-tower cooling system were to be utilized, the gasification process for a plant this size would still consume about 21,000 AF/yr. The smaller gasification plant proposed for Complex C would require about one-third the water needed for Complex A.

The Complex B commercial coal liquefaction plant of 100,000 bbl/day capacity equipped with dry cooling towers would consume 10,000 AF/yr. Evaporative cooling facilities more than double this figure.(44) For the 200,000 bbl/day plant, plus the power generating station discussed in these pages, the consumption is about 82,000 AF/yr.

Consumptive Water Use by Coal-Related Industrial Development - The consumptive use of surface and ground water will result at both of the assumed levels of industrial development discussed earlier in this statement.

Reiteration of previously estimated consumptive use requirements for the low-level and high-level coal developments on the Crow Reservation and Ceded Area is shown in Table 26.

Table 26 Consumptive Water Use at Low- and High- Level of Development

Industrial Complex and Use	Consumptive Water Use Approximate Volume in AF/Yr
Low-Level Development	
Crow Reservation	
Northern Mine	
Mine Use (5 x 10^6 Tons/year) (Dust control only)	140 1/
Southern Mine	
Mine Use (5 x 10^6 Tons/year) (Dust control only)	140 1/
Crow Ceded Area Mine	
Mine Use (10 x 10^6 Tons/year) (Dust control only)	280 1/
Total Low Level Consumptive Use	560

1/ Dust control will not be required during wet periods.

Table 26 (continued)

Industrial Complex and Use	Consumptive Water Use Approximate Volume in AF/Yr
High-Level Development	
Complex A (Crow Reservation)	
Mine Use (30×10^6 Tons/year) (Included with gasification plant)	
Gasification Plant (885 MM Scf/day)	76,000
Power Plant (120 MW) (Negligible)	______
Total Consumptive Use - Complex A	76,000
Complex B (Crow Reservation)	
Mine Use (30×10^6 Tons/year) (Included with liquefaction plant)	
Liquefaction Plant (200 M bbl/day)	58,000
Power Plant (1,360 MW)	26,000
Total Consumptive Use - Complex B	84,000
Complex C (Ceded Area)	
Mine Use (10×10^6 Tons/year) (Included with gasification plant)	
Gasification Plant (300 MM Scf/day)	26,000
Power Plant (40 MW) (Negligible)	______
Total Consumptive Use - Complex C	26,000
Strip Mine Developments	
Mine Use (3 mines times 5×10^6 Tons/year) (Dust control only)	420 1/
Total High Level Consumptive Use	186,420

1/ Dust control will not be required during wet periods.

The estimated volume of water needed for the low level industrial development may exceed surface water or shallow ground water supplies available in the immediate vicinity of such a development on the Crow coal resource area. However, ground water supplies from the deeper limestone aquifers could be utilized to supply as much as 500 gpm per well (800 AF/yr) to the mining complexes for use in dust control and coal washing operations.

Examination of the consumptive water use requirements for the high-level industrial complex gives an indication of the huge volumes of water required, assuming that present day cooling technology will be utilized in these plants. (See Appendix N for availability of surface water supplies). By the 1980's, dry cooling facilities may become feasible, reducing cooling water consumption at power plant installations to negligible quantities.

Consumptive water use at coal gasification and liquefaction plants will be reduced by a factor of one-half or more if dry cooling facilities are utilized. The dry cooling technology may be perfected by the time these facilities are constructed.

In conjunction with the Northern Great Plains Resource Program study, the Bureau of Reclamation conducted annual water year depletion studies of streamflow in the Bighorn River over the period 1936 through 1970. This study was intended to show the amount of surplus water available for other uses, assuming that 1970 depletions were applicable throughout the study period. Parameters utilized in compiling the study were established after all 1970 water diversions for agriculture or other uses were provided for. Minimum streamflow volumes, as outlined by the Bureau of Sport Fisheries and Wildlife, for maintenance of a viable fishery habitat in the Bighorn River were also determined. Positive residual flow volumes would then indicate years when surplus water would have been available for industrial or other uses, while minimum flows show the amount of deficiency. Table 27 indicates Bighorn River average and minimum flows. It also shows deficiences for the minimum flow year of 1961 and the surplus available for average flow years.

Table 27 Minimum and Average Flow Conditions with Fishery Habitat Requirements and Residuals Available for Industry

Item	Minimum Flow	Average Flow
Bighorn River flow in AF/yr x 1,000 (1970 depletions)	1,489.0	2,377.2
Fisheries habitat flow requirements (AF/yr x 1,000)	1,531.2	1,531.2
Residual flow available in Bighorn River (AF/yr x 1,000)	42.2*	846.0#
High Level Industrial Plant water requirements (AF/yr x 1,000)	186.4	186.4
Residual flow available in Bighorn River (AF/yr x 1,000)	228.6*	659.6#

* Deficiency
# Surplus

As may be noted, the minimum flow recorded in 1961 was below requirements for fish and wildlife habitat, a deficiency recorded in only two of the 36 water years. The further depletion of Bighorn River minimum flows by the amount of water projected to be used at the high level of industrial development results in a further deficiency of 186,420 acre feet, creating a total deficiency of 228,600 acre feet.

Storage facilities are, therefore, necessary for furnishing a reliable industrial water supply, in order to "average out" deficient runoff years with carryover storage from previous excess runoff years. Adequate storage capacity is available in Yellowtail Reservoir to meet the demand. During the occurrence of "average" runoff conditions, a water year surplus of over 650,000 acre feet would result. However, it is anticipated that some storage in Yellowtail Reservoir may have to be utilized temporarily during years of runoff surplus to adjust for runoff deficiencies.

A hypothetical Yellowtail Reservoir water supply balance, after projected coal mining and industrial development requirements on the Crow Indian Reservation and the Ceded Area are met, is shown in Table 28.

Table 28 Yellowtail Reservoir Water Supply Balance
With Annual Supply and Requirements

	Water Volume in Acre-feet (1,000's) 1/
(1) Surplus Yellowtail Reservoir water supply available for industral option contracts (all other uses of water supplied)	228.8*
(2) Low-level industrial development consumptive use (estimated)	0.6
(3) High-level industrial development consumptive use (estimated)	186.4

*Comprised of 110,000 AF Indian owned and 118,000 AF non-Indian owned.

1/ For details, see Appendixes M and N.

From Table 28, it is evident that low-level industrial development of the Crow coal resources will not appreciably diminish the availability of surplus storage in Yellowtail Reservoir for other uses. However, assuming high-level development or something approaching it occurs, almost all of this surplus water could be consumed by industrial plants utilizing present-day cooling technology.

Assuming that promising improvements in cooling technology will be forthcoming, and that these improvements are incorporated in future industrial plants described under the high level of development, it is estimated that as little as one-third of the amount of consumptive use shown in Table 26 may be required.

Water Quality Degradation - Strip Mining

Water quality will be degraded in the vicinity of the various mines and industrial plants that may result from development of the Crow coal resource area. The degree of pollution will be dependent on the size, location, and types of processes involved in the various facilities. The makeup and degree of water pollution possible from strip mining, power generating plants, gasification plants, and liquefaction plants will be discussed in the following paragraphs.

Effects of proposed coal strip mining operations on the hydrologic environment will be quite pronounced. Described in the following paragraphs are the probable effects on water quality due to strip mining operations in the Crow coal resource area.

Chemical Quality - Surface and ground water passing through strip mined or reclaimed areas will encounter material freshly exposed to weathering. This material may include minerals that are unstable in an aqueous environment; consequently, addition of solutes to this water is probable. Localized changes in type of water and concentrations of dissolved solids seem inevitable. Whether changes are desirable or undesirable depends on (1) the original composition of the water and (2) the uses to which it will be put. Conversion of a magnesium or calcium sulfate type water to a sodium bicarbonate type, for example, would possibly make it more desirable for stock watering and some household uses, but would make it less suitable for irrigation.

If increased infiltration into reclaimed spoil banks occurs, soluble salts may be leached from the shaly spoil material. Should adequate porosity and permeability exist, water containing the soluble salts may eventually reach the surface at the base of above-grade spoil banks or continue downward to the regional water table. Although the exact character cannot be predicted, the seepage water may be more highly mineralized than the existing ground water.

Residual water from precipitation or from irrigation of spoil bank material will undergo a deterioration in quality. This will result in an increase in the hydroxyl ion concentration and soluble salts such as nitrate, sodium, potassium, calcium, magnesium, and sulfates. Heavy-metal concentrations such as iron, manganese, lead, zinc, nickel, and molybdenum may also increase. Since little information on alkaline mine drainage is available, results of field studies now being conducted in the Colstrip and Decker areas will be useful for future predictions of environmental effects.

In the Colstrip, Montana, area highly alkaline mine drainage contributions to surface water supplies have occurred. Increased hydroxyl ion and total dissolved solids concentrations in the raw ground water have been noted (oral communication, Mr. Ernest Bond, Montana Bureau of Mines and Geology, June 19, 1973). However, this is an area of coal bed aquifer discharge, which would tend to magnify the alkalinity increase, and recharge water contributed to these coal bed aquifers would tend to reduce an alkalinity increase. The specific effects of the natural alkaline conditions on mine drainage water in the Crow coal resource area are unknown; however, the extensive presence of alkaline conditions would make the possibility of acid mine drainage very minimal.

Protection of ground water chemical quality will depend primarily on (1) the surface drainage configuration of reclaimed areas, (2) permeable characteristics of spoils material, (3) placement of toxic spoils materials in mining pits, and (4) rate of movement of seepage water through the spoils material into the aquifers.

Protection of surface water chemical quality will depend primarily on effluent quality allowed by Federal and State water quality standards.

Generation of acid mine water is not likely in the Crow coal resource area. Ground water in the Tongue River Member of the Fort Union Formation is alkaline, according to published and unpublished data collected by VanVoast. The shales in the member contain minor amounts of pyrite, but it apparently does not produce acid water. In the reworked spoils material that would be emplaced in the strip pits, the pyrite might be more readily attacked chemically, but available alkaline compounds would also be altered. The resultant drainage water may remain chemically similar to the present water for the following reasons:

(1) The sulfur content of the coal seams averages only about eight-tenths of one percent (0.8 percent). A general classification of sulfur content in coals follows:

Coal Sulfur Class	Sulfur Content (%)
Low	0 - 1
Moderate	1 - 3
High	+ 3

(2) The ground water in the coal beds is alkaline, having a pH range (measure of the hydrogen or hydroxyl ion concentration) between 7 and 9. The water will probably neutralize acids that form.

(3) The pH of the unleached overburden material is also highly alkaline.

(4) The water will have to be pumped from the mines to permit efficient mining. Thus it will have little opportunity to remain in contact with the exposed coal seams.

The Environmental Quality Council (1972) indicated that an acid drainage problem does not exist in most eastern Montana coal fields. (45)

Biological Degradation - Detention ponds formed in conjunction with or as a result of mining will be subjected to biological degradation. Stock ponds are presently subject to such contamination, however, so any change would be primarily an extension of an existing situation into new sites.

Contamination of ponds is produced by plants and plant debris as well as by animals. Algae, bulrushes, cattails, willows, and other water-loving or water-borne plants are characteristic of nearly all stock ponds on the Crow coal lands. Similarly, frogs, mosquitoes, aquatic birds, and other animals whose life patterns include presence of standing water are common; and livestock, game animals, and their predators also are visitors to the ponds. All these life forms are capable of changing the chemical quality of water in the ponds by adding or removing constituents.

Physical Degradation - If surface water passes freely across unconsolidated mine spoil material, whether as streamflow or surface runoff, it will tend to acquire additional sediment. Water will also pick up additional sediment as the gradient is increased. As water is released from detention ponds into streams or to subsurface aquifers, residual contaminants may also be transported.

Some contaminants can be removed from the water by detention, natural aeration, or filtration, but some will remain in the water unless they are removed by other physical and chemical treatment methods. Natural aeration and algal growth will tend to eliminate bacterial contamination, precipitate iron oxide, and minimize the oxygen deficiency that may have existed in the ponded water. Detention and filtration through sand and gravel will eliminate most of the coarser sediments and some of the solid organic debris as well as silt and clay particles. Federal and State water quality standards will be applicable to sediment contributions downstream of development.

Mine Dust Control - Application of ground water, obtained from one of the deeper aquifers such as the Hell Creek, Parkman, or Cloverly, for strip mine dust control may create a buildup of sodium salts in the soil. The sodium absorption ratio (SAR) of water from these aquifers may exceed a value of 26, indicative of a very high sodium hazard, and spreading such water over areas other than mine access roads would be detrimental to vegetative growth. However, utilization of water from the Madison limestone aquifer would not constitute a particular hazard, since the predominant dissolved solids content is calcium sulfate.

Water Quality Degradation - Industrial Parks

Power Generation (Steam) - One of the processes involved in the generation of electrical power by steam turbines involves the production of heat from burning of fossil fuels to produce steam from very pure water. The steam drives the turbine-generator section of the plant, is condensed (cooled) by fresh water from an outside source in flow-through or evaporative cooling systems, and is reused as boiler feed water. Makeup water is needed to balance steam losses.

These processes can result in several different types of water resource pollution, the nature and extent of which will vary with the location, availability and types of waterways present in a specific area. The three main sources of water pollution are: (1) thermal pollution, (2) pollution from plant wastes other than cooling waters, and (3) pollution from fly ash. These are described in more detail in the following paragraphs.

Thermal pollution from coal-fired steam turbine plants amounts to about 6,000 Btu's of heat energy, that must be dissipated by means of a suitable cooling process, for every kilowatt-hour of electricity generated. Cooling may be done by plant flow-through systems, cooling ponds, evaporative cooling towers, or dry cooling towers.

Flow-through steam generation cooling systems require huge volumes of water, on the order of 400 to 600 AF of water annually for each megawatt of capacity, and the temperature of the effluent ranges from 11° to 17° F higher than the original stream or lake water temperature. The impact of the increased temperatures on receiving streams will be:

(1) Lesser amounts of oxygen in gaseous form dissolving in water.

(2) Increased biological activity, diminishing already lowered oxygen levels.

(3) Extension of biologic growth periods which may upset ecological equilibrium.

(4) Increased sensitivity of aquatic life to toxic elements.

(5) Decreased value of water for drinking purposes.

The flow-through type of cooling system will not be feasible for mine-mouth plants on the Crow coal resource area due to inadequate supplies both of local water and that which might be imported economically, and to current water quality regulations.

Evaporative cooling towers, evaporation ponds, or dry cooling towers will be the only feasible methods for dissipating the waste heat from facilities for power generation on the Crow coal resource area. At the present level of technology, evaporative cooling towers are the most feasible method.

Evaporative cooling towers and evaporation ponds will require the consumptive use of water, whereas dry cooling or flow-through systems will not. From 10 to 15 AF annually per megawatt of plant capacity will be required for evaporative cooling. Release of water vapor to the atmosphere will create some problems from icing and fogging conditions during cold weather, and blowdown from evaporative cooling towers would be a possible water pollutant if not controlled. Evaporation ponds and dry cooling towers require much more land than do evaporative cooling towers. Also the evaporative losses from cooling ponds would tend to concentrate the dissolved-solids content of the pond water; thus seepage water or waste effluent from the ponds might contaminate existing gound and surface water supplies. The very size of the ponds would make it very expensive to seal or line them to prevent seepage.

Dry cooling tower systems are presently much more expensive than evaporative cooling tower systems. They require about five times as many towers and a corresponding increase in land requirements. Consequently, the cost of dry cooling systems is about five or six times greater than for evaporative cooling towers.

Wastes other than cooling waters would result mainly from the in-plant processes for softening, neutralization and demineralization of power boiler water, stack gas scrubbing operations, blowdown water from various plant processes, and other sources. The following tabulation more fully delineates these sources:(46)

(1) Hot concentrated saline water from boiler and evaporator blowdown. Normal operation would call for daily to weekly blowdown depending on boiler water conditions.

(2) Acid and alkaline chemical solutions used in cleaning boilers and other equipment. Cleaning would be done two or more times each year.

(3) Highly mineralized water from blowdown of cooling towers. A continuous or periodic bleed off of recirculating cooling water is necessary to limit buildup of dissolved solids.

(4) Wastewater from stack gas scrubbing operations. This would have to be a continuous process.

(5) Acid and caustic solutions from regeneration of ion-exchange.

(6) Hot alkaline water from blowdown of chemical softening plants.

(7) Acid or alkaline water drainage from coal storage.

(8) Cinder and ash dump drainage or slurry dewatering streams.

(9) Sanitary sewage.

(10) Oil, grease, and miscellaneous solid and liquid wastes.

Some of the major effects of these waste streams are:(46)

(a) Dissolved salts (phosphates, carbonates, sulfates, etc., and certain organic compounds) in boiler water blowdown can stimulate algal growths, slightly decrease evaporation rates, increase water hardness, and make the water more corrosive.

(b) Disinfectants (chlorine, copper sulfate, etc.) in cooling water blowdown can add taste, odor and color to receiving streams and reduce bacterial populations.

Reuse of the major wastewater effluent streams from a power plant, along with treatment of appropriate effluents, could be accomplished in the following manner by an efficient installation:

(1) Treated sanitary sewage effluent and boiler water blowdown could be used as part of the makeup water required for evaporative cooling towers.

(2) Blowdown from the cooling tower(s), along with wastewater streams from softening, demineralization, and stack gas scrubbing operations, could be used for quenching and slurry transport of furnace and fly ash to a treatment facility and disposal site. Separation of the liquid and solid components prior to disposal would be required.

Stack gas sulfur dioxide removal systems presently in use or proposed for the immediate future utilize dry or wet scrubbing processes in conjunction with alkaline or acid compounds and calcium carbonate (limestone and/or dolomite). The sulfur dioxide gas is converted to physically trappable solid compounds of calcium and magnesium sulfate, and disposal of these solid waste compounds by burial or stockpiling does not constitute a major water pollution problem. Future sulfur dioxide removal systems may involve sophisticated chemical processing plants which will produce marketable sulfur products but also require more complex wastewater treatment facilities.

Fly ash and furnace ash are solid waste products of power generation plants; they are produced in furnaces and stack gases from the combustion of pulverized coal and can create another water pollution problem. Fly ash weighs about 30 lb/ft^3 and constitutes about 10 percent of the coal burned. Although the furnace and fly ash are dry products, water is used to transport them in a slurry from the plant to the disposal site.

For every hundred tons of coal burned daily in a power plant, the annual requirement for fly ash storage amounts to about 2.1 acre feet. Depending on the Btu content of the coal, a 1,000 MW generating plant will burn from 2 to 3,000,000 tons of coal annually.

Uncontrolled disposal of large amounts of furnace and fly ash into the environment would have a serious adverse effect. Physical and chemical characteristics of the ash may contribute to great environmental pollution by causing increases in sediment loads and major changes in the chemical equilibrium of receiving streams. In the past, during floodwater conditions, plant installations have disposed of stored ash deposits in nearby streams. Accidental release of ash pond liquor due to failure of treatment facilities has also had drastic impacts on aquatic life in receiving streams.

Although burial of ash within strip mined areas is the most feasible disposal method, this could contribute to pollution of groundwater. If the ash is buried below the regional water table, or if leaching occurs from downward seepage of excess runoff or irrigation water through the overlying spoils material, the toxic leachate formed may become a groundwater pollutant. Ponding and evaporation of the decanted ash-transport water in a suitable facility would constitute a desirable and feasible disposal method.

Coal Gasification - Water is consumed and subjected to contamination in coal gasification plants during the following processes:

(1) Generation of steam for the gasification process.

(2) Cooling of crude gas and other products.

(3) Scrubbing cooled crude gases for removal of sulfur, tar, and dust.

(4) Quenching of gasifier ash and removal of slurry.

All of these gas process functions are contained in power gas and pipeline gasification plants that are currently proposed or in production, and that utilize coal as a fuel.

The gasification process and associated functions produce several synthetic petroleum liquids and gaseous products that constitute possible water pollutants. The products are comprised of synthetic gas (power gas or pipeline gas), crude tars, light oils, sulfur, phenols, naphtha, and ammonia, among others. The exact amounts and combinations of these products will depend upon the individual processes and types of equipment involved in a particular plant.

Wastewater that will pose potential water pollution problems and require treatment before reuse within the plant or release into the environment includes:

(1) Raw water treatment sludges

(2) Zeolite softener blowdown

(3) Boiler water demineralizer blowdown

(4) Cooling tower blowdown

(5) Boiler blowdown

(6) Ash slurry dewatering stream

(7) Waste gas liquor effluents from the gasification process

(8) Acid and alkaline chemical cleaning solutions

(9) Acid and caustic solutions for regeneration of softeners and demineralizers

(10) Acid or alkaline water drainage from coal storage facilities

(11) Raw domestic sewage

(12) Miscellaneous liquid and solid wastes.

Many of these wastewater streams are similar (although differing in magnitude) to those associated with the steam turbine-power generating processes. A major difference is the substitution of waste gas liquors from the gasification process for that of the stack gas scrubber effluent on power plants. However, the gas liquor effluent is much more complex chemically, and its composition will probably be similar to that of the process liquors derived from the production of coke fuel for the steel industry. An approximate analysis of the wastewater liquor from a coke plant before treatment is shown below:(47)

Table 29

Coke Liquor Components	Concentration - mg/l
Total Ammonia	7,000
Free Ammonia	4,000
Fixed Ammonia	3,000
Cyanide as HCN	20-100
Chloride	1,100-6,000
Sulfate	150-1,000
Phenols	400-3,000

Wastewater treatment will be required to reduce contaminants to acceptable levels before the water can be reused within the plant.

The treatment processes to be employed are similar to those used in petroleum refineries and are comprised of: (1) gravity oil separation with API separators, (2) dissolved-air flotation with or without addition of flocculating chemicals; and (3) biological treatment. The oil separators pretreat the water for removal of oil and limit the concentrations of sulfides, mercaptans, and phenols. Contaminant-stripping operations preceding biological treatment can be used to neutralize sour water and to remove ammonia, phenols, and cyanide.

The treated wastewaters from gas liquors, domestic sewage, and the boiler blowdown water may be used as part of the makeup water for the evaporative cooling water systems. The cooling systems, which lose water by evaporation, account for about 50 percent of the consumption in the gasification plant. Since these cooling water systems are of the recirculating type, they must be blown down periodically to prevent excessive buildup of dissolved solids.

This cooling tower blowdown water, along with blowdown from the softener and demineralizer equipment, may be used to quench ash from the gasifier reactors and transfer it in a slurry form to the dewatering equipment. The ash can then be dewatered and transported to the mine or other disposal site, while the wastewater may then be transferred to evaporation ponds. About 15 to 20 percent of the water is used in ash disposal, and the remaining 30 to 35 percent is converted to steam used by the process chemical reactions for manufacture of synthetic gas.

Furnace and fly ash, as well as waste sludge material from raw water, sewage wastes and gas liquor treatment processes, can be returned to the mine site for disposal by burial. Due to the possibility of ground water contamination, extreme care must be excercised with this method of disposal to ensure that the toxic materials in the ash and sludge will be contained adequately. Incineration, aerobic digestion or anaerobic digestion would also be suitable as treatment or disposal methods for some waste treatment sludges.

The elemental sulfur recovered in the gasification process can also be disposed of by burial, with little or no contamination resulting.

Coal Liquefaction - Water pollutants generated by coal liquefaction plants would be essentially the same contaminants generated by coal gasification plants.

Wastewater and Solid Wastes - Increased wastewater will result from the population influx associated with development of the Crow coal resources. In order to accomodate this population influx without causing excessive degradation of existing surface water supplies in the area, new and/or renovated sewage treatment plant facilities must be provided. Federal and State water pollution control standards would be applicable.

Should wastewater treatment facilities adequate to handle projected population increases not be constructed, the resultant impact upon the environment could be severe. Discharge of untreated or poorly treated sewerage into natural water courses could exceed the natural purification capacity of nearby streams and rivers, depending upon the particular set of conditions present. If this occurred, drastic changes in the character of aquatic life could result. However, the likelihood of this occurrence is remote since Federal and State water pollution control standards will be imposed.

Wastewater from processing coal for industrial use (at the mine or industrial plant) may require treatment. The crushing, screening, classifying, and washing processes involved in the cleaning and gradation of coal produces a suspension of fine coal, shale, clay, sand, and other particles in the wash water. The pollutants resulting from this operation would be suspended solids and dissolved calcium and magnesium sulfates, and iron. Lime neutralization, aeration, sedimentation, and other treatment processes would produce an acceptable effluent in conformance with Federal and State water pollution control standards.

Solid wastes from mining, conversion, or urban sources, will be disposed of in sanitary landfills or other approved disposal facilities in compliance with Federal and State standards.

A sanitary landfill would likely be less costly to establish and operate than an alternative such as incineration. If properly sited and operated, a sanitary landfill will cause insignificant pollution problems, whether from runoff or leachates contaminating streams or ground water, or from dust and odors creating air pollution and nuisance problems. If not properly sited and maintained, pollution in several forms can be extreme and the landfill will degenerate into an open dump. However, regulating agencies, particularly the Federal Environmental

Protection Agency and the State Department of Health and Environmental Services, should prevent this from happening.

The acreage required for a sanitary landfill will vary directly with the level of development and resulting population increase. A rule of thumb suggested by the U. S. Public Health Service in 1970, recommends that 15 acre feet of space per year be provided for each 10,000 people. Thus the acreage becomes significant only for the projected high level of coal development. For an influx of 40,000 people, if a landfill were designed for 20 years service at a 20 foot depth, 60 acres would be required. Presumably more than one site would be used, each close to a population center, wherever these may develop. Because of siting requirements for equipment storage, truck turn around, etc., the fenced acreage would probably be about 50 percent greater than that just required for the landfill.

CHAPTER IV

MITIGATING MEASURES INCLUDED IN THE PROPOSED ACTION

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Many of the adverse impacts can and will be effectively mitigated by the application of appropriate safeguards, operations and controls as plans for mining and energy conversion plants are developed. These mitigating measures are discussed under two general headings: (1) General Environmental Controls and (2) Specific Mitigating Measures.

GENERAL ENVIRONMENTAL CONTROLS AND LEGISLATION

Environmental controls will be discussed under four headings: (1) planning and development structures and organizations, (2) lease provisions and stipulations, (3) the mining plan, and (4) legal support.

Planning and Development Organizations and Structures

The most essential process in the orderly growth of any rapidly expanding community is the effective implementation of land use and development planning and control programs.

The success of these programs is dependent on the organizations which are charged with their implementation. The Big Horn County Planning Board and the Big Horn Area Planning Organization have the basic tools with which they can effectively bring about land use control programs. These include the subdivision ordinance which, with its self-policing principle, demands that a developer's plans and operations meet the minimum standards for good community planning, or his plat will not be recorded. With its provisions for space and facilities, this instrument will be effective in mitigating some of the adverse impacts associated with rapid development in the towns of Hardin and Lodge Grass.

The zoning ordinances adopted by Hardin and contemplated by Lodge Grass will, with proper enforcement, further insure orderly development.

The Crow Tribe has the opportunity to adopt similar ordinances and is giving serious consideration to such measures. The adoption of these measures would give the tribe the means for effective land use and development controls throughout the coal resource area. Whether or not these moves will occur in a timely manner is unknown, but progress to date is not encouraging.

The Lease Provisions

All mineral leases and mining agreements come under CFR 25, Sections 171 and 172 and CFR 30, Section 211. These codes stipulate the terms of the leases as well as the inspection and enforcement of compliance. The terms of the lease and/or agreement must comply with all applicable Federal and State laws which are relevant to appropriate resource utilization and protection.

The Crow Indian Coal Mining Leases contain several provisions for protection of the human and physical environment. As part of these lease agreements the lessee must:

(1) Comply with applicable Federal mining laws.

(2) Preserve the property and provide for the health and safety of the workmen.

(3) Refrain from dumping of waste materials or tailings on property outside the lease area.

(4) Not harvest, destroy, or damage timber without prior authorization of the Commissioner of Indian Affairs.

(5) Preserve and protect the natural environmental conditions of the land encompassed by the lease or land affected by exploration or mining, and take necessary corrective actions within the scope or normal soil conservation and stream and air pollution practices as follows: Operations shall

  (a) not pollute any surface or subsurface fresh water supply.

  (b) Control water supplies in conformity with existing Federal laws and minimize erosion and flood damage.

  (c) Terrace and landscape mining waste disposal areas.

  (d) Minimize air pollution which may result from the operations.

  (e) Submit a plan of implementation in accordance with 25 CFR 177.7 for approval by the Regional Mining Supervisor, U. S. Geological Survey.

In addition, the lessee will be liable for damages to persons and property resulting from the mining operations. The leased premises and mining operation will also be subject to inspection by an authorized representative of the Secretary of Interior.

The Mining Plan

Holders of permits, leases or other agreements are required to submit exploration and/or mining (including reclamation) plans for the approval of the Bureau of Indian Affairs, the Geological Survey and, where applicable, the approriate agency of the State of Montana. These plans specify in detail: (1) the placement of structures; (2) mining procedures, sequences and schedules; and (3) method and levels of reclamation.

Compliance to the provisions of the lease and objectives of the plan components is reviewed and inspected periodically by the Geological Survey, and appropriate modification and/or enforcement measures taken. A key element in this process is a periodic review which evaluates the adequacy of the plan and the effectiveness of the methods as well as the degree of compliance. This process permits a flexibility and adaptability in operations which encourages desirable modification so that the ojectives of the plan are fully met.

The Legal Support

In addition to the codes previously quoted, there are a number of Federal, State and local laws which will apply to the environmental aspects of development on the Crow coal resource area.

Federal Legislation - The following Public Laws, U. S. Codes, and Federal Regulations are applicable to coal leasing and industrial development on the Ceded Area and Crow Indian Reservation.

(1) United States Statues at Large:

- (a) Act of June 8, 1906 (34 Stat. 225) - An Act for the preservation of American Antiquities.
- (b) Act of July 9, 1956 (70 Stat.498) - Federal Water Pollution Control Act.

(c) Act of July 20, 1961 (75 Stat. 204; P.L. 87-88) Federal Water Pollution Control Act Amendments of 1961.

(d) Act of October 2, 1965 (79 Stat. 903; P.L. 89-234) Water Quality Act of 1965.

(e) Act of 1969 (83 Stat. 742; P.L. 91-173) - Coal Mine Health and Safety Act.

(f) Act of January 1, 1970 (83 Stat. 1073) - Declaration of National Environmental Policy.

(g) Act of October 18, 1972 (86 Stat. 816) - Federal Water Pollution Control Act Amendments of 1972. (See Section 400 - pollutant discharge permits program under the National Pollutant Discharge Elimination System.)

(h) Act of December 28, 1973 (87 Stat. 884) Endangered Species Act.

(2) United States Code:

(a) 7 U.S.C. 135 - Insecticide, Fungicide and Rodenticide Act.

(b) 33 U.S.C. 466 - Federal Water Pollution Control Act, as amended.

(c) 42 U.S.C. 1857 - Clean Air Act, as amended.

(3) Code of Federal Regulations:

(a) 25 CFR 177 (April 1, 1973 rev.) - Surface Exploration, Mining and Reclamation of Lands.

(b) Executive Order 11514, dated March 5, 1970 - Protection and Enhancement of Environmental Quality.

(c) 30 CFR 211 - Coal Mining Operating Regulations.

The preceding statutes should be referred to for specific details. In general, they contain the authority for regulation and protection of the social and physical environment, or they defer it to the individual states.

State Legislation - Certain State legislation relative to coal development is appliable to the Ceded Area and may be adopted by the Crow Tribe if it so chooses. There is question regarding its applicability to Indian lands, but the policy of the Department of Interior is to enforce the most stringent requirements available.

(1) On March 16, 1973, the State of Montana enacted a mining and reclamation act in the form of Senate Bill 94 entitled "The Montana Strip Mining and Reclamation Act." This act provides for:

  (a) Prevention of unreasonable degradation of its natural resources.

  (b) Restoration, enhancement and preservation of its scenic, historic, archaeological, scientific, cultural, and recreational sites.

  (c) Effective reclamation of all lands disturbed by the taking of natural resources.

Supervision and enforcement of the Act is accomplished by the Montana Department of State Lands through the issuance of an annual permit to the individual mining operators. Noncompliance of the operator with the requirements of the Act can result in suspension of the permit by the State. In addition, it is required that a comprehensive plan for surface reclamation and restoration be submitted and approved, along with certain other requirements, together with an adequate performance bond.

Violation of the provisions of this Act is subject to payment of a monetary civil penalty. A person who willfully violates these provisions will be found guilty of a misdemeanor and fined accordingly.

(2) Enactment of other legislation by the State of Montana for the protection of environmental life support systems is covered by the following citation:

  (a) State of Montana, Strip Mine Siting Act; Title 50, Chapter 16, Sections 1-17, RCM 1947.

  (b) State of Montana, Montana Environmental Policy Act; Title 69, Chapter 65, Sections 1-18, RCM 1947.

  (c) State of Montana, Montana Utility Siting Act; Title 70, Chapter 8, Sections 1-23, RCM 1947.

(3) The State of Montana has also enacted legislation for the protection of the air and water resources of the State. These include:

  (a) State of Montana, Air Pollution Act; Title 69, Chapter 39, Sections 14-25, RCM 1947.

  (b) State of Montana, Water Pollution Control Act; Title 69, Chapter 48, Sections 4801-4827, RCM 1947.

  (c) Act of 1971, Revised Water Pollution Control Act; as cited above.

Water Quality Standards - In addition, the following water quality standards will apply where applicable:

(1) 1962 U. S. Public Health Service Drinking Water Standards.

(2) State of Montana Water Pollution Control Council.

  (a) Water Quality Standards

  (b) Surface Water Use Classifications of Montana, October 5, 1967.

In summary, the preceding discussion indicates that the legal provisions for mitigating adverse impacts are available. The degree to which these successfully mitigate will depend on the effectiveness with which the authorized programs are enforced. For purposes of this study, it is assumed that enforcement will be highly effective.

SPECIFIC MITIGATING MEASURES

Social Impacts

The major mitigating measures that can be applied to any adverse social impact are those which the residents of the area exercise through community planning and control of development. Citizens involved in these processes can effectively mitigate adverse social impacts associated with rapidly expanding coal development by building plans and implementing programs which, (1) provide adequate community services in health, education, public protection and recreation; (2) develop adequate facilities for transportation, sanitation and communication; (3) develop appropriate commercial services and a responsible business community; and (4) encourage a community spirit which respects cultural, ethnic and philosophical variety.

As indicated at the beginning of this chapter, the basic structures are present to accomplish these programs. It remains up to the leadership of the area to make the structure work.

Social impacts, unlike others, cannot be effectively mitigated by pre-arranged contract. The coal developers can and will provide employment preference and training opportunities for local residents. They can and will, through company programs, taxation or royalties paid, provide a financial base which assists in mitigation programs. It is, however, up to the various interests within the communities and their leadership to conceptualize, plan and implement the required mitigating measures. As indicated, the community planning process has just begun. Whether or not it will be adequate in scope, depth, and timing remains to be seen.

Work training programs and job preference clauses in the mining plans and agreements will have a mitigating effect on the social stress which will accompany coal development. The first is provided for by the BIA's employment assistance program under the Comprehensive Employment and Training Act of 1973, as well as the training programs for local employees contained in the leases or other agreements.

Job preference in coal development positions for Crow Indians is a part of present mining operations. It is anticipated that this will continue to be an integral part of future agreements.

Economic Impacts

From an economic viewpoint, the most important mitigating factor is the income generated by coal development. Royalties to the tribe, employment and business income related to coal development and associated services, and the direct and indirect tax revenues these produce will make possible the funding of programs essential to an orderly, functioning community.

The effectiveness of these mitigating measures will depend on the people of the area and their ability to plan and implement programs which will provide the necessary community services, land use controls, and administrative structures.

Risk of Accidents

Safety programs will be required at both the mines and the energy plants. At the mines, accident prevention will be enforced by Mining Enforcement and Safety Administration, while at the energy plants, it will be enforced by the Department of Labor under the Occupational Safety and Health Act.

Historical and Archaeological Sites

Any area which is expected to experience any disturbance of the earth's surface will be carefully surveyed for evidence of historical or archaeological sites.

Lease agreements will include reference to the Antiquity Act of 1906. Under the terms of this Act, the destruction of historic or prehistoric ruins, monuments, or objects of antiquity with out permission of the Government is subject to fine or imprisonment, or both, at the discretion of the court.

Adverse effects on historical or archaeological sites will be further minimized by instructing the equipment operators to be watchful and alert management if they should discover any evidence of a site overlooked in the survey. Management will be responsible for notifying the proper State and Federal authorities of such evidence and appropriate assessment and salvage operations will be undertaken.

Transportation

Railroad and road plans are required to include provisions for protecting the environment to the greatest extent possible. Normal water flow and drainage should be uninterrupted by construction of bridges or placement of culverts over creeks, coulees, or water courses. Crossings must meet Federal and Tribal highway standards, including those for signals or underpasses. Cattle passes must be installed where property owners require them; syphons must be placed to carry irrigation water under tracks or roads, and fencing and cattle guards must be constructed as needed. Fertilization and reseeding must be included in the plans to repair any disturbed natural vegetation or reseeded area.

Improved roads will help ranchers or farmers to get their crops and livestock to market, and this will compensate, to some degree, the economic loss from a reduced agricultural base. Also, more areas will be available for hunting or other recreational activities. When completed, Interstate 90 is expected to accommodate any increase in arterial highway traffic, thus mitigating the adverse impact of increased traffic and its associated hazards.

Air Quality

Strip Mines - To alleviate the dust problem from stock piles and reclaimed areas, the piles will, wherever practical, be seeded with fast growing annuals such as rye and irrigated to promote rapid growth. A program of regular watering of the access and haul roads will be required to minimize dust problems on the unpaved surfaces.

The fugitive dust will not exceed the standards published by the Environmental Protection Agency as listed in Appendix B. Workers will be required to wear goggles and respirators, in accordance with Federal Coal Mine Health and Safety Act of 1969, to alleviate adverse effects of dust, although it should be recognized that compliance by the workers is often sporadic.

Loading facilities, crushers, and coal hauling trains will be required to water, cover, or otherwise enclose the loading and hauling equipment if large amounts of coal dust are emitted which drop air quality below EPA standards.

Energy Plants - Installation of wet scrubbers using any one of several alkaline additives will remove almost all the particulate matter and much of the SO_2 and other noxious chemicals from the stacks and vents in these plants, and these or other effective methods will be required. Fluorides are particularly susceptible to removal by scrubbers.(7) Technology for these air polution control devices is in the developmental stages and is improving almost yearly. By the 1980's, when the larger plants are built, there is reason to expect vast improvement in removal efficiencies. Proper design of stack heights will also improve air quality. These mitigating measures are analyzed in detail below for the three principal offenders--particulate matter, sulfur dioxide and the compounds of nitrogen.

Particulate Matter - As mentioned in Chapter III, without treatment the stack exhausts will emit large quantities of fly ash--eight pounds per million Btu burned for coal and 5.5 pounds per million Btu for char. Therefore, it will be necessary to add wet scrubbers to the stack. (Scrubbers would be required rather than electrostatic precipitators because of the need to remove SO_2 also.)

Properly designed scrubbers can remove 99 percent of the particulate matter from stack exhausts. Therefore, only about 0.08 pounds of fly ash (about the only particulate matter in the exhausts) would be emitted for each million Btu burned from the coal and .05 pounds per million Btu from the char. These are within the EPA standards.

A second EPA standard refers to air quality in the vicinity of the plant. The secondary standard would govern, which in effect states: The maximum quantity of particulate matter allowed near ground level on an annual basis is 60 $\mu g/m^3$ (geometric mean). On a 24-hour basis, the maximum is 150 $\mu g/m^3$. This standard could possibly be met by adjusting the stack height. To determine if it could, an analysis was performed to compute a stack height that would produce ground level concentrations falling within EPA standards.

To determine stack height, it is advantageous to construct a mathematical dispersion model of the plume and, through computer programming, to determine ground level concentration for a variety of conditions. This or other appropriate calculations will be made when the impact statement for a specific plan is prepared. For this preliminary report, however, a more approximate method will be used. It is the method discussed in Reference (26), and the computations are found in Appendix R. The results indicate that the stack height is governed by the NO_x concentration standard. Therefore, by meeting the standards for the gaseous pollutants, a plant automatically meets the standards for particulate matter. This is true for power generating, gasification or liquefaction plants.

Sulfur Dioxide - The coal is estimated to contain 0.888 pounds of SO_2 per million Btu's burned. At present, the SO_2 is difficult to remove with scrubbers or any other pollution control device. Until current wet scrubber pilot plant studies can be consistently extended to full-scale operation, it will be necessary to assume that only 50 percent of the SO_2 will be removed. If the scrubbers remove 50 percent of the sulfur dioxide, the quantity leaving the stack would be 0.84 pounds per million Btu, well within the standard.

The EPA has additional standards for SO_2. The ground level concentrations cannot exceed an annual arithmetic mean of 0.02 ppm, a 24-hour maximum of 0.10 ppm, and a one-hour maximum of 0.5 ppm. Stated in terms of micrograms per cubic meter, these values are 60, 260, and 1,300 respectively (assuming a conversion factor for SO_2 of 1 $\mu g/m^3$= 3.8 x 10^{-4} ppm). This EPA standard can probably be met with a proper stack height. The results of the analysis mentioned in the previous section and delineated in Appendix R indicate that a stack height sufficient to prevent ground level concentrations from exceeding EPA standards would be practical.

Thus for the power generating plants, EPA standards can be met in all SO_2 categories. The gasification and liquefaction plants have special problems from these emissions, but with each improvement in technology, these problems move nearer to solution.

Nitrogen Compounds - Less than 20 percent of the oxides of nitrogen will be removed by the scrubbers, but when a properly designed furnace is used, the amount of nitrogen oxides discharged will be less that 300 ppm.(28) If the total flue gas emission rate were 15 million pounds per hour (possible from the Complex B Plant), and the plant itself consumed 12.34 x 10^9 Btu per hour, the amount of oxides of nitrogen emitted will be less than 0.4 pounds per million Btu's burned.

The ground level concentration standards can also be met, as shown in Appendix R. A 560-foot-high stack would be needed at Complex B. It will be necessary to monitor fuel combustion to be certain the oxides of nitrogen are kept within standards.

Air Quality Monitoring Instruments are available which will monitor all aspects of air quality to determine compliance with State and Federal standards. Although the USGS has the responsibility of checking compliance with mining regulations, another agency might be designated to conduct the monitoring program for air quality.

In summary, by proper use of present technology, emissions can be controlled to meet current EPA standards.

Noise

Strip Mines - Noise from blasting can be decreased by use of selective explosives properly placed. Use of delays and proper weight charges can also reduce the sound level of the blast. In addition, blasting must comply with Bureau of Mines noise regulations. Workmen, after being made aware of high noise levels in specified areas, can take precautions such as wearing ear plugs.

Energy Plants - Much of the equipment can be placed within structures to dampen noise. Other equipment such as compressors will have mufflers installed. Throughout the plants, management must comply with the OSHA noise requirements.

The accoustic effect of trees in muting noise is an established fact. To disperse noise, the contractor will be advise to leave the timber standing as long as possible before cutting it in preparation for mining.

Reclamation of Disturbed Land

By enforcing the provisions of the leases, The Crow Tribe can achieve results comparable to State and Federal requirements, thus enhancing the chances of adequate reclamation.

Topography - Montana State Law limits the angle of slopes to 11°

or 20 percent with a maximum on the highwalls of 20° or 35 percent. Slopes will not be allowed to exceed these levels, as reclamation would be extremely difficult and success could not be assured.

In the course of mining and subsequent reclamation, extensive leveling of a large acreage can be accomplished to reclaim more of the land for agricultural use. In the land forming operation, there will be an opportunity to square off field boundaries for greater farming efficiency. Both of these will compensate losses in the agricultural base. Appropriate erosion control measures will also be required.

Where fishing lakes are desired as a planned part of the reclamation, the mining plan can be designed so a minimum of work will create lakes with gently sloped sides. However, either adequate surface water contributions or interception of the groundwater table will be necessary to create permanent lakes. If well drained rolling rangeland is the goal, this can also be achieved with proper planning and additional cost.

Replacing Topsoil - Before mining is started at any new mine on the coal resource area, soil studies of the overburden will be required, and a mining plan leaving phytotoxic and other detrimental material well below the top of the spoil piles must be submitted. Topsoil and other usable material suitable for supporting plant growth will be saved and replaced on the re-formed spoil piles.

The deep valley soils of mined areas will be stockpiled and placed back on the reshaped spoil material, as they are rich in organic matter and fertility. The best soil material is not necessarily the darkest, but is generally medium-textured, near loam or sandy loam, moderately permeable, and free of excess salts or other harmful constituents. Much of the surface soil is high in silt. High-silt soils are especially susceptible to water erosion and should be reestablished to vegetation as soon as possible. If these soils are not reseeded promptly, much of the soil placed back on the re-formed slopes will erode and leave raw spoil material exposed on the surface.

The sandy areas in the northern nonmountainous tracts are susceptible to wind and water erosion. A timely program of revegetation to hold these soils in place is essential.

To determine optimal reclamation procedures, an extensive soil testing program must be instituted prior to mining since in areas of deficient surface material, it will be necessary to use material from selected zones in the overburden, suitable as a root medium, to insure successful reclamation.

Some innovative land forming and preparation procedures, such as basin forming and the use of special mulches, promote soil moisture retention. This will include the replacement of soil organisms including insects, nematodes, and earthworms, but especially soil fungi and bacteria, which are concentrated in the A horizon (topsoil).

Revegetation - The Bureau of Indian Affairs at Crow Agency, Montana has proposed a revegetation guide to follow appropriate land reclamation. It includes two approaches: (1) The restored area would be fenced and then sown to a mixture comprised mainly of introduced grasses and legumes for pasture, to be managed separately from native range.

(2) The high walls, other odd corners and steep areas not large enough to fit into the grazing pastures would be fenced and planted to shelterbelts and wildlife plantings.

The mining operator must provide a revegetation plan using a seed mixture that includes enough kinds of plants to insure that vegetation can be established on each of the wide range of habitat types (climate, soil, slope, and aspect) likely to result from the land reclamation procedures. This can be accomplished not only by the use of tame grasses and legumes, but also by use of a wide variety of suitable native plants which are available for sowing on restored lands.

The coded symbols following each species in the Appendix F plant list provide a partial key to the suitability for various uses of the plant species known to be present on the areas proposed for strip mining.

The Montana Agricultural Experiment Station is conducting revegetation studies at a strip mine site near Decker, Montana. It is testing 50 individual seed mixtures including 70 grass, forb, and shrub species. The list includes species expected to be adapted to a wide variety of climate, soil, slope and aspect or direction of exposure. The object of the tests is to "select species for reclamation which are vigorous, heat- and drought-resistant and alkali- and salt-tolerant." A number of seeding rates are being tested, as well as fertilization rates and land forming methods. The findings of these studies are expected to add significantly to the technology of reclamation.

Optimal and timely revegetation will allow the earliest possible return to the original use of disturbed land for crops, livestock, wildlife and recreation. This will significantly mitigate short- and long-term economic and other use losses.

Measures for Protecting Wildlife

The reestablishment of the wildlife habitat through proper reclamation of the mined lands (an example is described in "The Montana Strip Mining and Reclamation Act")(48) is a viable means of attracting wildlife to the mined lands. The use of native plant species, established in the locations and relative abundance characteristic of the area before mining, must be adhered to in order to provide a well diversified and balanced habitat that can sustain a wide variety of wildlife.

The following additional measures can be used also:

1. Livestock grazing can be temporarily eliminated from lands adjoining mining development areas to provide additional food and cover for wildlife forced into these areas. The non-grazing buffer zone should be at least twice the size of the land being mined and should be maintained until reclamation of the mined lands is accomplished to the point where wildlife can again be supported.
2. No livestock grazing should be allowed on lands under reclamation until the range condition is determined to be more than adequate to support livestock as well as wildlife.
3. Power transmission lines can be contructed in a way that will prevent electrocution of large raptorial birds.(11)
4. Prairie dog towns should not be disturbed where they are not directly involved with mining sites.(11) Any towns discovered to contain black-footed ferrets can be totally protected from disturbance or destruction regardless of location.
5. Large tree snags and potential nesting sites can be left standing.(11)

6. Eagle and prairie falcon nests can be protected from disturbance within at least a one-half-mile radius of the nests.(11)

Recreation

All companies mining coal or operating plants in the area will be required, by State law or tribal regulation, to restore the land to as near its original condition as possible after mining or other activities are completed. Since reclamation will be an ongoing process at all times during mining, only a small portion of the total Crow coal resource area will be blocked off or unusable for recreation at any time. Eventually the entire area will be restored and, to a large extent, available for recreational purposes depending only on tribal desires and resolutions.

Limiting development on special areas will insure that sites critical to recreational development are safeguarded. Studies to determine the location and extent of such sites will be required.

In addition to the regular recreational uses now available, fishing, boating and waterfowl hunting could be added if the last cut in any strip mine is left open. This would depend on agreements between the Crow Tribe and the company, as well as on the availability of water of suitable quality.

Water Resources

Quantity - Apportionment of surface and ground water resources for consumptive use in development of Crow coal resources will be determined in accordance with Indian water rights, intrastate water compacts, or State water rights, whichever is applicable.

Quality - Maintenance of water quality standards in and adjacent to areas of coal development on the Crow coal resource area will be required.

The proposed mining and industrial development of coal resources must comply with all water quality standards set forth in the Federal Water Quality Acts. The State of Montana water quality standards under the State Water Pollution Control Act, while not applicable to the reservation proper, will also serve as a control or guideline. The section on Environmental Controls and Legislation in this chapter may be referred to for the exact citations. Methods used to maintain water quality standards might include monitoring, physical treatment, and chemical treatment. Regulatory agencies responsible for compliance with these standards are the Environmental Protection Agency and the Department of State Lands, State of Montana.

Surface Water - Surface waters will be protected principally by diversion around strip-mined areas prior to and during mining, or by lining of stream channels across reclaimed areas after mining. Surface runoff can be diverted away from mine areas by properly constructed channels above the final highwall. However, such channels will need to be planned so that their slopes are gentle enough to prevent erosion or they must be lined.

Effluent from the mine sites or industrial plants may contribute to pollution or ponds, streams, or ground water. Such effluent will have to be monitored, and treated if necessary, to insure that undesirable physical characteristics or chemical constituents are not introduced into these waters. Evaporation or treatment ponds may have to be sealed to prevent percolation from reaching shallow ground-water supplies. Ponds will require adequate storage capacity to prevent accidental spills into surface water supplies. Provisions for safe disposal of solid wastes containing toxic materials must be made to prevent contamination of surface waters.

Ground Water - In some cases, special ground water protection practices will required. For instance, where coal can be mined economically only from the valleys, the groundwater in the alluvium may be depleted, since alluvial aquifers would be removed from the mined areas. Restoration of the original terrain may not be possible, since removal of the coal would leave the reclaimed surface lower than existing terrain. Water conservation could be accomplished by leaving small openings in the final cut for drainage purposes and constructing ponds or lakes as a planned part of reclamation.

Sediment Detention - Water flowing across spoil banks or through strip-mined areas may carry sediment into watercourses unless preventive steps are taken. Similarly, wind blowing across unreclaimed strip-mined areas will acquire sediment and redistribute it. Cover crops of hay, grass, or grain and mulching of the disturbed topsoil will reduce the erosive power of falling rain, blowing wind, or running water. Grassed waterways not only hold topsoil in place, they also trap some of the sediment carried by the water.

CHAPTER V

UNAVOIDABLE ADVERSE ENVIRONMENTAL IMPACTS

Social Impacts

The additional income that Crow people will get from coal development may create changes which may be viewed as social problems. Also, the introduction of new ways of life and the trend toward urbanization will require social and cultural adjustments by members of the tribe.

There will also be an increase of about 1,000 or 10 percent in the population of reservation and surrounding towns at the low level of development, and an increase of up to 43,000, or over 400 percent, at the high level. This population increase, accompanied by the urbanization process, will increase social problems in the small towns around the mining and energy plant sites.

Without Effective Land Use Control - If relatively effective controls on residential and commercial development are not implemented, many more non-Crow families than anticipated in the analyses in Chapter III would probably settle in the Little Bighorn Valley. The number of families could range from 3,000 to 8,000 at the ultimate level of development, and the impacts from such an influx of non-Indians would very significantly dilute Indian influence on the community society. Control by the Indians of their own reservation would become very difficult at best and in all likelihood impossible. It would become equally difficult to retain those residual parts of the Indian cultural heritage which will be functional in accommodating Indian values to a developing society. Also, services would be extremely inadequate to meet the combined needs of the present population and the influx of new workers and their families.

With Effective Land Use Control - Even with a relatively effective land use control plan, some parts of the reservation will likely be severely impacted at the high level of development. The social impact will probably be greatest at Lodge Grass, where a substantial influx of non-Indians can be expected. The population ratio would likely change from the present Indian majority, and social problems might arise, since the economic as well as political and social structure would be dominated by non-Indians.

Economic Impacts

The adverse economic effects that could be expected from the proposed action are minimal at the low level of development. There will be a reduction in grazing income of approximately $4,020 per year on the reservation and $1,970 per year on the Ceded Area during the time of active operation of the mines, farming income will drop approximately $1,425 per year on the reservation and $700 per year on the Ceded Area.

Under high level development, grazing income would be reduced by $17,742 per year on the reservation and $4,856 per year on the Ceded Area. Farming income would be reduced by $6,300 per year on the reservation and $1,725 per year on the Ceded Area.1/ Although it is assumed

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1/ Based on $5.00 annual lease rate per AUM and $12.50 per acre lease rate for cropland.

that the grazing capacity will be returned to its approximate premining level after full restoration of the mined area is accomplished, the interim economic impact cannot be avoided.

Services

Severe negative impacts such as shortages of school, health, public protection and available goods and services are likely to be felt for at least several years before the public and private services can be expanded to meet the demand created by a rapidly increasing population. After this trying adjustment period, the impact will not likely be severe.

Accidents

Although a slight decrease in the accident rate is anticipated, a slight to moderate increase in numbers of accidents, injuries, and deaths is likely to occur at the different development levels despite such mitigating measures as traffic control and mine safety precautions. This increase in numbers can be expected because of the anticipated increase in population, automobile traffic and mining activity, while the decreased rate will result from safety programs and devices.

Historical and Archaeological Sites

Even if coal developers meet all their legal responsibilities and take the proper precautions, there is no total assurance that undiscovered sites will not be overlooked and destroyed. This lack of assurance infers that some loss of archaeological value is unavoidable if undiscovered sites do, in fact, exist.

Transportation and Utilities

The increased traffic resulting from development in the Crow coal resource area will overburden existing below-standard secondary roads. The result will be not only considerable inconveniece for travellers, but delays and higher costs in freight deliveries.

When completed, I-90 is expected to handle any increased arterial traffic: however, US 212 is likely, even with modernization, to suffer some of the same effects as the below-standard secondary roads.

In spite of the most effective preventative measures, increased trackage and train frequency will raise the number of associated accidents. Some inconvenience for non-rail traffic at crossings is also inevitable.

No unavoidable adverse impacts are expected to result from increaseed air traffic.

After reclamation is completed, the only unavoidable adverse impacts from power and pipe lines would be of a temporary nature resulting from occasional breaks and leakage. Such problems are anticipated in spite of the most careful preventative measures.

Noise

A large increase in noise level is unavoidable. As discussed in Chapter III, the major effects will be felt by the workers and by those living or having business within about a mile of the mines or plants.

Workers in the mines and plants will experience noise levels above 70 dB when laboring near operating equipment. When the level exceeds 90 dB, exposure of more than an hour or so can result in physiological problems such as impaired hearing and nervous disorders. The extent and permanence of the impairment will depend upon numerous variables such as frequency or octave level of the sound waves, time and frequency of exposure, and proximity to the source. All these effects can be mitigated if the workers wear plugs or ear covers, but because of the tendency toward carelessness, many workers may not always use the devices. Residents near the plants will be outside danger areas (sound levels near 50 dB are found a mile from the equipment). However, there may be an annoyance factor which is both difficult to estimate and unavoidable.

People living near the spur lines will be annoyed by noise from the unit trains, although they will probably be far enough from the track so the decibel level will not be too damaging or offensive.

Air Quality

Even though dust control will be required within the mining area and on the railroad cars, there will be more degradation of air quality along new and heavily traveled unpaved roads.

It has previously been shown that air pollution can be controlled to meet EPA standards. However, this analysis was very approximate, and the conditions used were not the most severe possible. The most severe would be encountered if an air inversion occurred during a time of persistent high pressure in the area, and the wind rose shown in Chapter II indicates this would be unusual.

At any rate, air pollution from the energy plants will result even if the emissions meet State and Federal standards. If the standards are met, the pollution will be slight - but far from zero, since the most effective emission control programs still permit the discharge of some pollutants and particulates. A small quantity of fly ash, sulfur dioxide, nitrogen oxide and trace elements will always escape to the atmosphere. This is unavoidable.

In particular, the SO_2 emissions for the gasification and liquefaction plants will not always meet EPA standards. Thus, the state of the art would presumably have to improve before these plants could be constructed. Considering the time frame used in this report, improvements in SO_2 removal techniques would be probable by the time plants were built; however, this would have to be carefully studied at the time the plant design is developed. Incidentally, other references indicated that the SO_2 emissions could be reduced, but in view of the study contained in Reference (35), the amount of reduction appears in question.

The personnel working in the energy plants, as well as the plant and animal life within several miles downwind, will be the living things most affected. Most game life will probably move far enough away to be able to tolerate the emissions, but numerous birds, burrowing mammals and lower forms will be eliminated until reclamation is fully completed. Susceptible vegetation downwind from any pollutant source would be subject to foliar damage as phytotoxic emissions and dust are produced.

Secondary effects could occur if chemicals such as selenium and fluoride come in contact with plants that are significant constituents in an animal's food chain. These consequences discussed in the references cited in Chapter III. In addition, the Environmental Impact

Statement prepared by the State Department of Health and Environmental Sciences for the Generating Plant at Colstrip(7) does a good job of listing the harmful effects. In short, it is evident that whether or not the emissions meet air quality standards, the long-term effects may be injurious to both plants and animals.

Portions of the larger complexes, such as the cracking unit in the liquefaction plant, would probably not meet air pollution standards if built today.

Land

Topography - To varying degrees, the removal of coal during mining operations will modify grades and elevations of the land surface. This will result in the permanent alteration of the topography and may create local areas of either sharper or flatter slopes than before. Improper-placement of spoils, insufficient reclamation, and erosion, may cause drastic changes in land forms. The surface mining operations may increase natural soil movement, change drainage patterns, and otherwise alter the size, shape and positions of topographic features. In addition, the land surface will be altered by the construction of plants and reservoirs, and, to a lesser degree, new roads and rail lines.

In most cases, it would be impractical or impossible, and not necessarily desirable, to restore the land to its exact original contours. A change in topography does not necessarily mean that productivity or use is changed, or that the esthetic quality is damaged. However, unless great care is taken in land reclamation, degradation of these qualities is highly probable.

Soils - Suitable topsoil in adequate amounts for reclamation will be difficult to obtain in some areas. These include:

(1) the 40 percent of the Wayden-Regent soil association where Wayden soils are dominant. (See No. 16 on the soil association map, Chapter II, page 96).

(2) the 30 percent of the Ringling-Searing-Arnegard association where Ringling soils are dominant (No. 13 on the association map).

(3) the 60 percent of the Thedalund-Midway association where these two soils are dominant (No. 11 on the map).

The depth of usable material in these shallow soils average only 10 to 15 inches. This scanty amount will be very difficult to stockpile. There are about 100,000 acres involved in the coal resource area where stockpiled topsoil would be inadequate for reclamation. Extensive core sampling of these areas is needed to determine whether usable layers of overburden might be present to supplement or substitute for topsoil. If such usable soil material is not found, revegetation on these shallow soil sites will fail, or at least will be very difficult.

Wind erosion will no doubt become a problem until begetation is re-established on the soil. If heavy winds or rains strike an area before vegetation has taken hold, erosion could severly damage a reclamation effort and impede the normal flow in the drainages or creeks by adding tons of silt to the swales and stream beds.

Land Use

Although, even at the high level of development, less than five percent (about 16,000 acres) of the Crow resource area will be shifted from agricultural to high-level industrial use, the change will be much further-reaching.

The social and economic changes have already been discussed, but it might be noted that the very face of the land will change. Industrilization and urbanization could very well alter the attitudes of the people toward agricultural and recreational use of the land.

There is little doubt that some land would be taken out of any productive use for the foreseeable future. Similarly, some areas will be under noncontrolled intensive use, creating slum conditions. The extent of these will be dependent on the efficacy of the land use planning and controls program.

Vegetation

All vegetative cover at any strip mining site and its support facilities will be removed. At the low-level of development a total of 19,345 acres would be disturbed with about five percent (967 acres) being cropland. At this level 3,405 acres of land would be disturbed and unreclaimed at any one given time. At the high-level a total of 57,135 acres (2,857 acres of cropland) would be disturbed with a total of 12,845 acres being unreclaimed at any given time. The degree of adverse impact will depend upon the rapidity of revegetation; (including restoration of a partial tree cover on the area, a process which will take at least several decades).

Certain plant species, especially the most desirable, in a climax community are extremely slow in reentering a site where they have been destroyed or disturbed and initial sucess in replanting may be very limited. Therefore, the composition of the plant cover on the disturbed area will change, at least in the short run.

Land slippage, or solifluction, on fine-textured sloping land is very common on the steep grasslands of the Wolf Mountains. Since the deep-rooting of trees generally reduces or delays such damage, any loss of trees, either from mining or from chemical pollution, would of course accelerate this type of erosion.

Fish and Wildlife

Impacts on wildlife that cannot be avoided include: (1) removal of up to 12,845 acres of habitat at any one time from use by wildlife (high level; (2) actual destruction of some animal life such as rodents, insects and lower forms; (3) disturbance through noise, human instrusion, and physical development associated with the mining and industrial operation. Any or all of these elements will reduce wildlife numbers of such important species as prairie dogs, grouse, and big game. Big game would migrate back into the mined area soon after revegetation. Grouse booming areas would probably be permanently destroyed even after revegetation. The burrowing species, such as prairies dogs would also be permanently affected with in-migration from other areas, being an extremely slow process.

Fish will be adversely affected in direct proportion to the amount of pollutants allowed to enter streams, and by any reduction in flows caused by mining. The proposed mining areas contain few game fish, but important downstream fisheries in Rosebud Creek and the Tongue, Yellowstone, and Little Bighorn Rivers would be adversely affected.

Esthetics

During the mining operations, the spoil banks, draglines, loading equipment, coal stockpiles, conveyor belts and gasification, liquefaction or other plants will intrude upon the natural scenic character of the area. These intrusions may be esthetically offensive to many people as they view the area.

The restored areas will be characterized by the recontoured and reclaimed landscape masking the former overburden piles. If fully adequate reclamation is accomplished, the appearance may not be displeasing in itself, but the texture, lines and land forms will be unnatural among the more primitive surrounding land. The resulting view, though it may be uniform and pastoral, may be less pleasing to some people than the original view.

If haul roads or other man-made alternations are left intact, or are only partially obliterated or removed upon completion of mining, the new land forms, lines, colors and textures would be lasting disfigurements to the countryside.

The energy plants with their high towers and stacks assembled in a visually disorganized manner will offend the esthetic sense, as will the multihued buildings, houses and mobile homes. Even more offensive may be the odors of sulfides and mercaptans that would be emitted.

Recreation

At both levels of coal development the major impact on recreation will result from increased population and the associated increase in demand for recreation. This increase may also cause closing and posting of private land. This may result in overuse, and some deterioration of available recreational resources on and near the study area is unavoidable. However, in view of the total potential, this should be minimal if good management of the recreation resources is practical.

Another adverse impact will result from the unavoidable loss of land base suitable for certain recreational purposes. The change of water use, especially at the high level of development, may affect the recreational potential, and tribal restrictions on non-member use of many recreational facilities will limit the available land base.

Water Resource Effects - Strip Mining

Surface Water Consumption - Substantial amounts of indigenous surface water may be used to furnish water for mining activities such as dust control and revegetation. Ground sources will provide much of the water for mine use but up to 1,000 acre feet per year may be from surface sources at the high level and none of the low level. Water so used may be evaporated, transpired, retained as soil moisture for an indefinite time, or lost to ground-water recharge.

Surface Water Quality - Pollutants may be contributed to the surface waters including organic and inorganic contaminant residuals from sanitary facilities, coal processing facilities, stock ponds, as well as sediment from the strip pits, spoil banks, and backfilled areas. Although wastewater treatment plant facilities will minimize the organic and inorganic residuals, and detention dams and ponds will minimize or eliminate the sediment loads, system breakdowns or mismanagement is possible.

Acid mine drainage is not expected to present a major water quality problem in the Crow coal resource area.

Ground Water Consumption - Ground water exceeding 560 acre-feet per year is likely to be used for coal washing and dust suppression, wetting of haulage roads, irrigation of reclaimed spoil banks, and employees facilities. This will be approximately the same usage for both levels of development because at the high level surface water will be utilized as well. To the extent that these are new uses which remove ground water from shallow pre-mining regimens or deeper aquifer systems, they are consumptive uses, for the water will not be readily available for return to former sources. Some will be evaporated or transpired, and the remainder will become either surface runoff or ground-water recharge.

Removal of the shallow overburden and coal bed aquifers during mining will contribute not only to the loss of ground water contained within the disturbed area, but also to the loss of recharge areas. Although this loss of storage and recharge waters may create only a minor adverse impact on the regional bedrock aquifers, it would probably constitute a major impact on the much less extensive alluvial aquifer system. Consequently, spring flow, shallow wells and stock ponds intercepting regional or locally perched alluvial water tables (or potentiometric surfaces) within the mined area or the area of influence created by mine drainage may be adversely affected. At least some of these losses are unavoidable. Ranchers presently using wells, springs, and stock ponds in the area will be adversely impacted.

Ground Water Quality - Pollution of shallow ground water supplies will very likely occur to some degree from the leaching of excessive undesirable solutes dur to: (1) saturation of the overburden backfill material used to reclaim strip mining sites, and (2) release of treated wastewater effluents containing excessive residual contaminant levels.

Water Resources Effects - Industrial Plants

Surface Water Consumption - Important of very large amounts of surface waters (as much as 185,000 acre feet per year at the high level) from sources on and off the reservation will be required to fulfill the consumptive demand that may be created by potential energy manufacturing industrial plants (see Appendix N for industrial water commitments).

Depending upon the magnitude of industrial development allowed, the availability of surface water resources of this region may be adversely affected during extended drouth periods. Commitment of large volumes of surface water supplies for industrial consumptive use may adversely affect other sectors of the economy such as agriculture, both on and off the Crow Reservation. As an example, irrigation users may be limited in their water supply during critical seasons in dry years.

Surface Water Quality - Accidental release of untreated or partially treated wastewater effluents may occur. The probability of these occurrences can be made extremely remote through adequate engineering design of plant facilities. However, should an accidental release occur, even without negligence, the contributor will be liable for damages.

Ground Water Consumption - Shallow ground water supplies are inadequate even for minor industrial plant consumptive use. Production of ground water from one of the deeper artesian aquifers for minor industrial use may comprise a ground water "mining" operation if this use exceeds the available recharge. Unrestricted artesian flow or continuous pumping from a well may result in localized depletion of ground water storage in the aquifer. The magnitude of this depletion would depend on the aquifer utilized and the amount of consumptive use.

Ground Water Quality - System failure or mismanagement may cause pollution of shallow ground water supplies with industrial plant-treated wastewater effluents. There may, for instance, be leakage from detention and evaporation disposal ponds. Treatment of the effluents in compliance with Federal and State water quality standards, as well as the construction of disposal pond facilities with leakproof linings, will minimize, but not eliminate, the possibility of such occurances.

CHAPTER VI

RELATIONSHIP OF SHORT TERM USE TO MAINTENANCE OF LONG TERM ENVIRONMENTAL PRODUCTIVITY

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RELATIONSHIP OF SHORT-TERM USE TO MAINTENANCE OF LONG-TERM ENVIRONMENTAL PRODUCTIVITY

Development of the Crow coal resources will permanently change many aspects of the social, biological, and physical environment of the area. Additionally, many short-term losses will be experienced during mining.

These losses will be a trade-off that the Crow people must weigh as they consider the benefits that they can expect through increased income from the sale of coal.

Socio-Economic Effects

The local people, primarily the Crow Indians, can expect to go through some changes in their way of life or contemporary culture. Whether these changes are desirable or undesirable, depends on local action and personal point of view.

Development of coal and the associated industry will provide Indian employment of between 250 and 725. In addition to more jobs, average income of the Indians is expected to rise substantially. Together with local expenditures by industry, the net result will be a major increase in regional income.

In the short term, all services will be overloaded. Service facilities including schools, health centers, utilities, and transportation systems will be overtaxed. In the short run, all of this overcrowding will create a hardship on the Crow Indian people. However, as facilities catch up to the increased population, more and better services should be available to all.

Income to the landowners will be shifted from agriculture and forestry. Royalty payments together with salary and business income will be of great enough magnitude to more than offset the loss of income from present land uses.

Some long-term effects on archaeological, historical and scenic sites will occur because of disruption of the surface by the mining operation. Excavation will permit some paleontological exploration that would otherwise not be practical.

Air Quality

Air quality will be reduced during mining and plant operation. In the longer term the air quality should improve again after mining stops.

Land Resource Use

Loss of agricultural production will accrue from two sources; loss of land and loss of water. At the high level, approximately 642 acres will be removed from crop production at any one time and 12,203 acres of grazing land will be temporarily disturbed during project development. Stock water sources will also be disturbed. After the land is revegetated, agricultural production will again occur.

Several thousand acres of forest land will be lost from production for a minimum of 80 to 100 years unless mining is restricted by greenbelt zoning. Some of the mined or industrial sites will likely never again be able to support a commercial coniferous forest.

There will therefore be a short-term removal of land from agriculture, and a longer term forest disturbance.

Wildlife

The mined area will be lost to wildlife use until the area is revegetated and mining activity is diminished at a particular site. Since it is recognized that wildlife use may not be the primary goal of the reclamation program, some permanent change in wildlife habitat may result.

Water Resources

Since agriculture and residences are the primary users of water in the Crow coal resource area, it is these uses that will be affected by mining.

At the low-level development, the projected disturbance of water during coal development is limited to well production and water available from the coal bed aquifers. The curtailment of use from these shallow water sources may be remedied by using deeper water sources in the long run.

At the high-level development, including associated industrial plants, the effect will not only be the disturbed aquifers, but also surface and ground water consumption by the energy conversion plants. After mining and plant operation stops, the long-term effect will be from the disturbed aquifers. Although the extent of these effects cannot be forecast with certainty, present users of shallow ground water in areas downflow from the mines must anticipate utilizing deeper aquifers for domestic and agricultural purposes.

Coal Resource Use

Other uses for coal have been considered such as its conversion to synthetic gas and liquid petroleum products. In addition, reconstituting its form completely to provide such consumer goods as plastics or even food products is within the realm of possibility. However, when the coal has been used for thermal production of electricity, it will not be available for other possible uses.

CHAPTER VII

IRREVERSIBLE AND IRRETRIEVABLE COMMITMENT OF RESOURCES

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The contemporary culture of the Crow Indian people will almost certainly be irreversibly changed with the increased economic activity in the area and the influx of non-Indian workers.

If any archaeological sites are not discovered prior to mining, their loss will be a permanent irreversible commitment of resources. Some historical items, like pioneer relics and moveable objects, could be removed and saved; however, the site itself will be lost.

If the mining operation is carried out according to existing and probable future plans, as much as 4,500,000,000 tons of coal will be mined and consumed. These resources cannot be replaced and will not be available for future alternative uses. Clinker, sand, and gravel will be used as aggregate material and for all practical purposes will be lost.

The surface of the ground will be changed. In place of the present topography, the recontoured ground will have a regular undulating appearance. Land used by energy plant sites will probably be taken out of agriculture forever. These land changes will be a commitment of resources.

A change in the plant composition after reclamation is almost inevitable. After many years, when the climax vegetative community is finally established, its composition will be different from, but not necessarily inferior to, what it is now.

Ground water from deep aquifers will be used for varied mining operations and industrial plant needs, excluding cooling. Water so utilized will be committed for the life of these projects. Depletion of ground water in the coal bed aquifers will also occur. Imported surface water will be utilized for process and cooling purposes in industrial plant complexes and would be committed for the life of these projects.

Some reduction in water quality can be expected by sediment from mine and ponds. However, monitoring of impounded run-off and drainage water quality and measurement of sediment contributions will minimize the permanency of water quality damage. Some seepage of leachate through reclaimed spoil banks to the potentiometric surface of the coal bed aquifers may occur. Disposal of industrial plant effluents through inadequate holding or evaporation pond facilities may create shallow ground water pollution problems. The possibility of accidental discharge and the occurrence of minor levels of water quality degradation in streams exists.

CHAPTER VIII

ALTERNATIVES TO THE PROPOSED ACTION

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ALTERNATIVES TO THE PROPOSED ACTION

In this statement, no specific development levels or coal mining sites are proposed. The statement is based on two definite, though assumed, levels of development on the Crow Reservation and its Ceded Area. Therefore, it is important to consider various alternatives and their relevancy from the standpoint of environmental and socio-economic acceptability. Various leasing and development alternatives are discussed in this chapter, along with alternatives for transportation, mining, coal use, reclamation, land use, tribal entrepreneurship, energy sources, and others.

The primary decision will be the level and kind of resource development to be encouraged or permitted. Other choices will involve the methods to be used, the location and timing, as well as the environmental and other requirements to be imposed.

In considering these alternatives, it must be borne in mind that the primary purpose of leasing the Crow coal-bearing lands has been to provide income and employment opportunities to the Crow Tribe. Secondarily, mining the Crow coal would help to alleviate the current national energy shortage.

The alternatives discussed present a number of general courses of action open to the Crow Tribe. These involve the levels and locations of coal development. Other more specific alternatives are directed toward methods and objectives of coal use.

LEVEL OF DEVELOPMENT

Three possible alternative levels of coal development will be discussed: (1) A low level with a production range of 20,000,000 to 30,000,000 tons annually, (2) a mid level with a production range of 30,000,000 to 60,000,000 tons, and (3) a high level with annual production of 60,000,000 to 90,000,000 tons. For analytical purposes, it is assumed that only the high, and possibly the mid level, will convert coal to energy or other products on the reservation or Ceded Area. All coal produced at the lower levels will be shipped by rail.

No Action (No further development)

It is conceivable that the Crow Tribe would decide against any coal development beyond its present commitments. This is based on a resolution submitted in 1974 by the Crow Tribe to the Secretary of the Interior calling for cancellation of all leases.1/

In such a course of action, the tribe would: (1) refuse to approve any future mining plans, (2) prohibit any new lease or renewals of existing leases, (3) deny any expansion of Westmoreland lease or scale of operation, (4) keep the Crow Tribe from entering into coal development with or without an entrepreneural partner, and (5) exclude possibilities for any other form of coal development.

In effect, such an alternative would place an indefinite freeze on all Crow coal development. One result would be that all environmental and social-economic change would be left to more evolutionary processes

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1/ See Appendix C

and major influences would be from other than coal development. The impacts and opportunities which have been the subject of the main analysis of Chapters III and V will not occur.

Considering the tone and content of the July 13, 1974 Crow Tribal Resolution, this alternative must be considered viable.

No Development

This alternative would involve the cancellation of all existing leases, permits, mining plans and other contractual agreements regarding coal development. It would also prohibit any action on future coal development. Although this alternative appears extreme, the Crow Tribe's July resolution lends it a definite degree of credibility.

The impact from adopting such an alternative would be similar, but more severe, than the preceding one since the Crow people would not only forego possible opportunities, but would also lose incomes they are currently enjoying.

The outcome of such an action would be ultimately determined by the Secretary of Interior or a Court of Law. If legal leases or other contractual agreements were cancelled, a court might find that the tribe and/or the Government would be required to pay damages.

ALTERNATIVE LEVELS OF FUTURE DEVELOPMENT

Three alternative levels of coal development will be considered. All three are assumed to use coal from locations most economically advantageous to the coal development companies. For each of the levels the factors which bear on their impacts will be listed.

Low-Level Development

This alternative limits development to a mining rate of 20 - 30,000,000 tons per year, all of which would be shipped out from operations on existing leases.[1] All coal could be taken from existing leases on the Ceded Area, thus leaving Indian surface resources relatively untouched and avoiding any more significant social stress on the community. Similarly, at this level, mining could be confined to the east slope of the Wolf Mountains where, although Indian surface resource would be disturbed, major social stress could be avoided. (Locational alternatives are discussed in a later portion of this section.)

1. Environmental impacts on the land base would be relatively slight, as indicated in the previous analyses of low-level development.
2. Environmental damage and social stress on the reservation would be minimal, and the way of life and cultural heritage of the Crow people would be changed at a rate slow enough to permit adaptation to change. Also, services would be developed to keep pace with population growth.
3. The rate of development would allow time for effective land use planning to be initiated.
4. The employment opportunities and income generating capacity of

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[1] Recent agreements between the tribe and Westmoreland alone project the mining of 19,000,000 tons per year by 1990.

the coal resource to the Crow people would be an estimated 225 jobs and $8,000,000 in royalties at the 20,000,000-ton level, and about 335 jobs and $12,000,000 in royalties at 30,000,000-tons. Annual royalties on a per capita basis would amount to $1,420 at the lower limit and $2,131 at the higher.

Mid-Level Development

It is assumed that 30,000,000 to 60,000,000 tons will be mined annually at this level. At the 30,000,000-ton level, all coal could be shipped out from Ceded Area operations, while near the upper limit, reservation sites would be mined up to 15,000,000 tons available as an option for use in energy conversion or other processes, either in or out of the coal resource area. The option to convert or process a portion of the coal would broaden the potential market for Crow coal and also increase the potential for a higher income base and greater employment opportunities for Crow and other local people.

1. At the lower limit of the mid-level production range the socio-economic and physical impactswould be similar to those outlined in the low level. Over the entire range, employment opportunities for Crow Indians would be increased to as many as 450 jobs, and royalties would be $12,000,000 to $24,000,000 annually, or $2,131 to $4,263 on a per capita basis.
2. The option to have conversion plants would enable the Crow people to fully evaluate the likely socio-economic and land use consequences of large-scale mining and industrial development on the reservation, in the Ceded Area, and in adjacent areas, and to develop appropriate control measures.

3. Near the upper limit of the production range (over 45,000,000 tons annually), there would be a much increased danger of serious environmental damage such as loss of wildlife habitat and water quality degradation particularly if a rapid rate of mining expansion and/or industrialization on the reservation were encouraged. Unless the pace set for expansion on the reservation is very deliberate, and land use and community planning are speeded up, it is highly probable that coal development on the reservation would outstrip the capacity of the planning system and undesirable impacts on the services and lifestyle of the Crow people would occur.

High-Level Development

The high-level alternative envisions an annual coal production rate of 60,000,000 to 90,000,000 tons. The lower half of this range envisions that one energy conversion plant be established on the Ceded Area, while the 90,000,000-ton level represents the maximum development as discussed in the statement's previous impact analyses.

1. The population would expand to several times that of the present, from 10,000 to over 45,000 in Big Horn County.

2. Annual royalty incomes would be high, reaching levels of $24,000,000 to $36,000,000 annually, or, on a per capita basis, $4,263 to $6,395 to Indians.
3. Opportunities for employment and the development of skills would be very abundant especially for Indians.
4. At first the expanded population and economy would overtax Education, Health, Transportation, Government and other services. Later the expansion of these facilities will provide better services than was originally available.
5. The use of the coal resource could create a local energy supply for other associated industrial uses, further expanding the local economic base.
6. With a high level of industrial development there will be some environmental degradation in spite of the most stringent mitigation measures. Unless effective land use control and community development programs are formulated and applied, very severe adverse socio-economic, biological and physical impacts are likely as the upper limits of the projected high-level development are reached. Present progress in planning does not indicate that fully effective programs will be developed.
7. The Crow people may find themselves a minority in their own reservation and their way of life will be changed at a rapid rate which will not allow for adaptation by the local Crow Indians.

AREA OF DEVELOPMENT

Exactly where the Crow coal resources are developed will have a very definite influence on the degree and type of impact, both beneficial and adverse. Restricting coal development in any way to specific locations will also be a major determinant in the level of development. The implications of limiting the location are discussed under five different alternatives.

Development in the Ceded Area Only

This is the only area where coal development is now occurring, and present projections indicate that Westmoreland resources will be mining nearly 20,000,000 tons annually by 1990. Also, AMAX representatives have indicated that they are now in the process of preparing a mining plan in connection with their leaseholding in the Ceded Area.

It is estimated that there are approximately 1,000,000,000 tons of recoverable coal in the Ceded Area and this activity and interest indicates a possibility that these two companies could be mining coal at the mid level (30 million tons annually) by 1990. This could conceivably be accomplished under the existing leases.

Restriction of coal development to the Ceded Area would minimize impacts to the physical environment on the reservation. Such an alternative would mean less aesthetic, social, and cultural hardship on the reservation while still providing some economic benefits to the Crow Indians. However, it is unlikely that the Ceded Area alone could produce substantially more than 30,000,000 tons per year, thus the potential economic benefits would be diminished. The ceded lands off reservation would bear the brunt of impacts from mining as described in earlier sections.

It is likely that the large majority of this coal would be shipped to off reservation areas. The environmental impacts on these areas would be essentially the same as those for the low level of development.

Development of coal limited to the East Slope of the Wolf Mountains

This alternative location is on the reservation and can be seen on Map 5, page 86. Shell Oil Company has recently submitted a plan for their initial mine. Shell has also informed the Crow Tribe of long-range plans to mine about 24,000,000 tons by 1990--16,000,000 tons to be shipped to distant points, and 8,000,000 to be used for conversion. Gulf also has a permit in this area but has not gone to lease.

Although the total amount of the recoverable coal lying east of these mountains is not known, preliminary findings indicate that it is about two-thirds of the reservation total or 2,000,000,000 tons. This area alone could support mining at levels approaching the high level analyzed in the main body of the statement (over 60,000,000 tons annually). However, this would involve the issuance of additional leases.

Human impacts to the Crow Reservation such as changing lifestyles and dilution of cultural values would be reduced substantially because the primary transportation route and urban development could be directed away from the area where the Indians now reside. The esthetic values of the Wolf Mountains such as sharp cliffs, flowing creeks and tall pines would also be protected under this alternative, while at the same time large-scale coal mining and processing could be permitted. However, this isolation of coal development may also result in lower employment opportunities for the Crow Indians.

Since it is not anticipated that these resources would support mining to 90,000,000 tons annually, the royalty benefits would be reduced by approximately one-third of the high level.

Development Only in the Ceded Area and East of Wolf Mountains

It is entirely conceivable that the coal resources of these two areas could support coal production at or near the highest level (approximately 90 million tons annually). Whether conditions would be conducive to developing conversion plants may be questionable, but there is no reason to believe that plants cannot be constructed in adjacent off-reservation areas. This alternative would, of course, call for the issuance of additional leases in the area east of the Wolf Mountains.

Limiting coal development to these two locations would result in the cumulative environmental impacts described under the two previous alternatives.

Development Only on the Reservation

This alternative would prohibit any further development on the Ceded Area and could restrict development to present operations. To reach even the low level of development this alternative would call for the issuance of new leases.

Limiting development to the reservation would mean that the impact from coal mining would not be on the Ceded Area. On the other hand, depending on how much development the tribe might want, the impact levels on the reservation would increase over those described in the impact analyses, probably at some geometric rate. Impacts to the human environment such as social disruption resulting in changes in cultural heritage on the reservation would be even more acute than those on the physical environment because reclamation may heal the scars of strip mining.

All Crow Coal Reserves

This is the alternative which is used throughout the statement's analyses of impacts and discussed in previous chapters. This alternative would involve extensive development on all presently permitted areas, including the non-leased Crow reserve area. Such development of all Crow coal reserves implies action at about the high level of development previously discussed in this statement.

The beneficial, social and economic impacts would be greater royalties to the Crow Tribe, more jobs and more complete service facilities. The adverse impacts would be the dilution of the Crow way of life through the increased industrial activity. This could mean loss of cultural heritage and even the eventual extinction of the Crow language.

DEFER FURTHER DEVELOPMENT

One alternative is to defer further development until adequate and effective land use and community development controls are implemented. These controls could be developed by a tribal land-use commission or by an area-wide commission.

A Tribal Land Use Commission

Such an entity would give the Crow Tribe or a designated subgroup the responsibility, and presumably the appropriate support and authority, to act (1) to develop land use plans, (2) to pass ordinances, and (3) to enforce all provisions of the charter of a planning commission.

This approach would leave all responsibility squarely in the hands of the Crow people. Since much of the surface ownership of the land in the coal resource area and the Little Bighorn Valley is in the hands of non-Indians, the non-Indians may not be fully cooperative to Indian control. Such a possibility could be minimized by having non-Indians represented on the commission on an appointive basis. This would have a diluting effect on Indian influence, which might be more than offset by the increased effectiveness of the land use controls and the political acceptability of the planning commission.

An Area-Wide Land Use Commission

This approach conceptualizes a land use planning commission appropriately structured and authorized to cover a legally delineated area within Big Horn and Treasure counties, areas which would be heavily affected by large-scale development of Crow coal reserves. An existing organization, the Big Horn County Area Planning Organization, now has responsibility covering Hardin, Lodge Grass, all of Big Horn county, and much of the Ceded Area.

Such a commission would include representation from both Indian and non-Indian interests in some proportion to the resident population of the area. It would have full power to develop plans and enforce their implementation on both Indian and non-Indian lands. Both the plans and enforcement procedures would be under the purview of the commission's board and would be subject to the board's policies. It would, of necessity, have to conform to the appropriate tribal, State and Federal statutes but, within this framework, be an entity capable of establishing rules having the full force of law.

The impact of deferring development of coal until viable land-use controls are effective would reduce the income to the Indians in the short term but in the longer term would protect the contemporary culture of the Indians from undue change and would also lessen the impact on the land through land-use controls. The two different types of commissions discussed would have similar impacts if both Indians and non-Indians are represented on the commission boards.

Modification of Leases

Existing leases could be modified to include any or all of the following: (1) partial leasing, or limited-area leasing, with mining plans approved within an existing permit area; (2) leasing with stipulations as to the allowable (a) type of mining, (b) levels of development, (c) reclamation, and (d) adverse environmental and social impact; and (3) remunerative escalation clauses.

Partial Leasing

Partial leasing would consist of limiting the mining of coal and other mineral resources, or alternative coal-use developments, to those areas where impacts on the existing economy, physical and social environments and esthetics would be minimized as determined by environmental studies.

Impacts of partial leasing would be a reduced level of negative effect on the services of the Crow Reservation, lifestyles of the Crow Indian people, and the land-use change. It would have similar effects in off reservation locations in some direct proportion to its reduction in coal production.

Leasing with Stipulations

Among the stipulations which could be included in new mineral leases or added to existing leases via mining plans are:

1. The amount and type of mining for maximum efficiency. Such measures will ensure the removal, in a single pass, of the greatest economically feasible coal tonnage per unit of land.
2. Levels and types of reservation mineral resources development including mining, production, and alternative coal use. A basis for limiting the level of development would be the identification of some maximum desired tribal economic level, or maximum level of degradation or depletion of other resources in the immediate area.
3. Acceptable levels of reclamation for a particular lease area.

This alternative could give the Crow people a chance to obtain large royalty payments while at the same time lessening the negative impacts of lifestyle changes and land-use shifts.

Remunerative Escalation

Escalation of remuneration to the Crow Tribe (based on current coal prices) for the mining and use of their coal or other mineral reserves under these leases could be provided for.

This escalation of royalty payments would increase the income to the Crow people while slowing down the negative impacts until the local services can be expanded to serve the growing population.

DEVELOPMENT ENTREPRENEURSHIP ALTERNATIVES

There are several alternative forms of entrepreneurships which pertain equally to industrial, commercial and residential development. In general, the broader the range of options available, the more selective the planning can become, and the better the chances of environmental and social health in a community.

These alternatives may be classified into four major groups.

Indian Entrepreneurship

Tribal Entrepreneurship - Under this alternative, the Crow Tribe would take the entrepreneurial initiative. Presumably it would take, through a fiscal agent, the necessary steps to recruit professional management and assistance. Under very limited operations, the tribe might accomplish this with the assistance of BIA.

Individual Indian Entrepreneurship - With this course of action, individual Indian entrepreneurs or entrepreneurial groups would obtain the necessary financing and technicial assistance in much the same way as that suggested for the tribe.

Both of these alternatives have the impacts of utilizing Indian input and influence as well as yielding possible rewards. The negative impact is the chance for failure because of a lack of capital and management experience.

Non-Indian Development

Non-Indian development similar to what is now proposed through leasing is a third alternative. In recent efforts at coal development, this has been the dominant approach in the Crow coal resource area.

A negative impact of this alternative is that not as much control of the basic resource is likely and little positive identity with the Crow community or significant local political leverage can be expected.

Cooperative Effort or Partnership

A cooperative effort or a broad partnership arrangement between non-Indian entrepreneurs and the tribe or individual Crow Indians could combine the advantages of each if proper training for tribal leaders and individual Crows could be arranged and adequate motivations and institutional structures were provided.

Impacts would be increased Indian income and level of control. The negative physical and enviromental impacts could then be minimized according to the Indian goals.

ALTERNATIVE SOURCES OF INDIAN INCOME

Several alternatives exist with respect to the financial development of other resources available to the Crow Tribe. Among these alternatives are agriculture, industry, recreation, and minerals development. At the low level of coal development there would be approximately $8,000,000 annually from royalties. At the high level the royalties could amount to as much as $36,000,000.

Agriculture

The present net earnings from the 1,791,776 acres of Crow Indian lands in agricultural use is approximately $2,393,000 annually. Significant income expansion from this land is doubtful.

Income to the Crows could conceivably be provided through expansion of the Indian land base by purchase of private land both on and off reservation. It would require an additional 4,325,000 acres of range land to provide an income equivalency for the low level coal development and 20,000,000 acres for the high level. Comparable figures for dry cropland and irrigated cropland are 640,000 acres and 80,000 acres for the low level and 2,880,000 acres and 360,000 acres for the high level. Since these acreages are several times the present Crow ownership, it is extremely doubtful that sufficient land could be purchased for the Crow Tribe to provide income from agriculture equivalent to that possible from coal development.

Other Mineral Development

Oil and gas - Several small oil and gas fields on the Crow Reservation were discovered as far back as 1913. The total production from Indian leases in these fields, prior to January 1, 1965, amounted to over 153 million cubic feet of natural gas and almost 1,500,000 barrels of oil. The total value of the oil and gas amounted to slightly more than $2,000,000, out of which $263,051 in tribal royalties were paid. The exploration and development of oil and gas is progressing as rapidly as possible and will continue with or without coal development.

Metallic minerals - There are reports of copper, placer gold and uranium deposits on the reservation. However, it is unlikely that without extensive prospecting any commercial quantities of metallic minerals will be discovered.

Nonmetallic minerals - the Crow Reservation has numerous and sometimes extensive deposits of nonmetallic minerals such as betonitic clays, shales, clinkers, gypsum, pumice, limestone and dolomite, and sand and gravel. Future development possibilities for these deposits will depend upon supply and demand. With the development of coal resource in the area, demand for nonmetallic minerals will increase because of facilities construction and plant operations. Limestone, dolomite and sand and gravel will probably comprise the bulk of nonmetallic minerals use.(1)

In conclusion, the anticipated monetary value to the Crow Tribe of other minerals development will be insignificant compared to that possible from royalties and income due to development of coal resources.

Recreation

Several opportunities exist for alternative land-and water-based recreation development on the Crow Reservation. These include hunting and fishing, water sports, winter sports, and family vacation-type enterprises.

Hunting and fishing licenses to nonresidents of the Crow Reservation have been withdrawn because of the past abuses of these privileges. Although the issuing of permits on an indiscriminate basis may have resulted in problems in the past, another avenue that may be attractive is controlled big game hunting. This could consist of trophy hunting for native species of big game or the introduction of compatible exotic game species from other areas, or both.

It is possible that a controlled program involving issuance of separate fishing permits, stocking of streams, and good management of a game fisheries industry could also result in a profitable business enterprise.

Water sports facilities developed on tribal land which fronts on Bighorn Lake would generate some revenues from Billings users. Boating, sailing and water skiing would comprise the major uses.

A winter sports complex in the Bighorn Mountains could provide skiing and other facilities for a localized area. However, similar facilities are easily accessible to the main local area user population in Billings.

Development of dude ranch summer vacation facilities in the Bighorn Mountains near sites for water sports, fishing and other attractions could provide another limited source of income to the Crow Tribe.

An individual summer home-site development project similar to the Hawley Lake Community on the Fort Apache Reservation in Arizona may also present another attractive recreational investment potential.

Impacts from recreation development would include income to the Crow Indians participating in recreation enterprises. The employment numbers would likely be lower than coal related employment. Recreation could also be developed with or without coal development.

Industrial Development

Attraction of clean industrial development to the Crow Reservation would be an attractive alternate to coal reserve development. Manufacturing operations require suitable sources of raw materials, transportation, manpower, utilities and other community necessities, and an accessible and ready market for the finished product.

The Crow Reservation is relatively isolated from any other major industrial areas and does not offer many of the above requirements of industry. The possible extent of reservation-based industrial development would depend upon the ingenuity and aggressiveness of the Crow Tribe in seeking out and convincing appropriate industries that these enterprises would be mutually beneficial.

Since no industrial development proposals have been made, the impacts of industrial development are undetermined.

Forestry

Harvesting of timber and the manufacture of forest products are areas that might prove attractive. In the recent past, from one to three million board feet of timber, with a value of $20,000 to $150,000, has been harvested annually on the Crow Reservation. Developable timber reserves could eventually support an annual harvest of up to five million board feet--three million board feet from Indian land and two million board feet from private land within the reservation boundaries.

This development alternative could not match coal as a source of income to the Crow people.

Other Income Sources

The Federal Government could exchange Federal coal from another location for that on new or proposed Crow coal lease areas. The exchange would serve to transfer the environmental impacts to another location. This would be a trade-off between Indians and non-Indians.

Other coal used as a substitute for the Crow coal will have similar impacts but at different areas.

The Federal Government could also purchase the coal outright from the Crow Indians if new leasing is rejected. While there are no accurate estimates of the total amount of funding needed for a buy-out, the huge tonnages of on-reservation coal reserves indicate that the figure would be large. This alternative may require new legislation if it is to be considered.

Income to the tribe and to the tribal members could also be provided through Federal grants and welfare assistance, sources which have been providing a substantial portion of the income to the Crow people over the past several years. Increased use of these income sources can be expected unless large-scale development of Crow Indian resources takes place.

Environmental impacts under these income alternatives would be the same as for no development except that the Crow Indians would receive income benefits.

ALTERNATIVE LAND RECLAMATION OBJECTIVES

Most areas associated with mining, construction, and temporary rights-of-way are eventually abandoned to another land use. A variety of potential land uses can be considered after surface disturbance and topographic alterations have occurred. Land uses after mining which are considered as options in the Crow coal resource area include grazing, wildlife habitat, recreation, cropland, urban and commercial development, and multiple land use combinations.

Methods of reclamation should be chosen with a specific land use objective in mind. Such post-mining land use alternatives are summarized in Table 30 on the following page. All tracts might not be adapted to all possible uses.

Grazing

It is assumed that after reclamation most land in this area will be for livestock grazing. Grazing is best suited to areas having flat to gently rolling topography with adequate reservoirs. The land surface should be improved by topsoiling, fertilizing, mulching, and mechanical treatment. Both native and introduced species of vegetation can be used successfully.

Surface soil materials must be capable of supporting vegetation which will provide adequate ground cover for erosion control and some harvestable forage. The topography should vary from flat to gently rolling, with no slopes steeper than 4 to 1, and it would be advantageous to have gentler slopes so that machinery could be used to redistribute topsoil and to reseed. Highwall areas should be reduced to an angle of repose that does not represent a hazard to grazing livestock. A 2 to 1 slope or less would be desirable. The selected revegetation species should be compatible with the soils, climate, season of grazing use, and adjacent native vegetation. Livestock fences and watering facilities would be needed.

Rehabilitation of lands solely for grazing purposes would affect and limit other land uses such as wildlife habitat and recreation. For example, fences would interfere with some species of wildlife and with recreation use, and the less diversified vegetation suitable for livestock forage would limit wildlife diversity and would be less attractive for recreational purposes.

Table 30 Post Mining Land Use Alternatives*

		Grazing	Wildlife	Recreation	Urban and Farming	Commercial
Reclamation Alternatives*	Topography - Landform					
	1) Flat - Gently rolling	1	2	2	1	1
	2) Rough - Significant relief	3	1	2	4	4
	3) Highwalls (reclaimed)	3	2	3	4	3
	4) Lakes and Reservoirs	1	1	1	2	1
	Soil					
	1) Surface with topsoil	1	1	1	1	1
	2) Surface without topsoil	4	4	3	4	2
	3) Rebuild soil structure	1	1	1	1	1
	4) Fertilize and Mulch	1	1	1	1	2
	5) Mechanical surface treatment	1	1	2	1	2
	Revegetation					
	1) Native species	1	1	1	4	2
	2) Introduced species	2	2	2	1	2
	3) Irrigation	1	2	2	1	2

*Alternatives may be selected singly or in combination.

Legend: 1 = Desirable alignment of reclamation with land use.
2 = Acceptable alignment of reclamation with land use.
3 = Undesirable alignment of reclamation with land use.
4 = Unfeasible alignment of reclamation with land use.

Among other considerations, water impoundments for livestock would be limited in size and would have very little value for recreation or aquatic habitat. Also, competition would exist between some wildlife species and livestock, so wildlife populations would be reduced. Finally, increased erosion would occur with the removal of protective vegetative cover by grazing. Other vegetation would be trampled and the soil surface would be compacted.

Wildlife Habitat

Areas to be used primarily as wildlife habitat should be reshaped to a rolling topography with slopes no steeper than 3 to 1, and highwalls should be reduced to the same slope to eliminate hazardous conditions. Although many wildlife species prefer areas with rough or significant relief containing lakes and reservoirs, the slope should not exceed these standards. The soil should be stabilized by topsoiling, fertilizing and mulching, and on slopes of 3 to 1 or steeper, by special structures to prevent erosion. Topsoil replacement will be necessary for the reestablishment of vegetation.

A large variety of native shrubs and grasses would be planted, along with some trees. Limited introduction of species would add variety to the habitat, and the greater the variation in habitat and food sources, the greater the variety of wildlife that can be expected to repopulate the area. Sagebrush seeding would be highly desirable along with other plant types.

Water impoundments would be designed specifically for wildlife habitat, and stagnant waters would not be tolerable. Highwall areas, if used to facilitate lake formation, would have to be fenced to protect wildlife.

Rehabilitation of lands for wildlife habitat would shorten the time necessary for repopulation of the area. Increased steepness and roughness of topography would prevent use of the land for some forms of recreation, urban and commercial development, or crops. Also, the potential for livestock grazing would be reduced since the type of vegetation would not include preferred forage species.

Rougher and steeper topography would result in the increased instability of surface soils. Heavy wildlife use could result in excessive removal of plant cover and increased soil erosion.

Recreation uses, especially those involving vehicles and large numbers of people, would be limited in order to permit more sensitive wildlife species to occupy the area.

Recreation

Recreation is possible on all types of landforms, depending upon the type of activity contemplated. Access roads, trails, and plant species would be planned to be compatible with slope and soil characteristics. Also, hazardous conditions would have to be eliminated.

As with other land uses, topsoil should be replaced on all disturbed areas and revegetated with specified grasses, shrubs, and trees which can stabilize and beautify the surface.

Water impoundments for recreation use would be built to specifications meeting the approval of the State Board of Health and preventing stagnant pools from forming. Shoreline slopes should not be greater than 3 to 1, or they should be bermed as an additional safety measure.

Recreation use of reclaimed lands would result in increased littering, and the increase in off-road vehicle use would mean the destruction of plant cover as well as increased erosion and compaction of soils. Air pollution from vehicles and dust would occur, and some pollution of impounded waters could be expected. Also, the numbers and diversity of wildlife would be reduced, and some species sensitive to human disturbances would be eliminated.

Livestock use would be curtailed or totally absent from heavily used recreation areas, and water impounded for recreation use would be unavailable to industry and agriculture.

This alternative could provide sorely needed opportunities in the event of significant population growth in the area.

Cropland

It is not generally considered a practical objective to return surface-mined areas to cropland production except for small areas with limited surface disturbance such as rights-of-way or gravel pits. Surface topography should be flat or very gently rolling with slopes no steeper than 5 to 1, and good soil material stockpiled and replaced to a depth of at least two feet over a suitable overburden of sand, gravel, or porous rock. Fertilizing, mulching and mechanical seeding are necessary and under some conditions, irrigation will be required to insure success.

Recreation use would be eliminated or severely restricted during parts of the year, and since most cropland is seeded to single crops such as wheat or alfalfa, wildlife habitat would not be diversified.

Finally, livestock grazing would be limited to specific seasons of the year.

Economic and local demand for farm products would bear directly on alternative agricultural uses.

Urban and Commercial Development

Urban and commercial development would be best suited to flat to gently rolling topography with lakes or reservoirs. Topsoiling would be desirable but not essential for this type of development. Fertilizer, mulch, and mechanical treatment would be needed to establish desired landscaping; and introduced and native grasses, shrubs, and trees would be used.

Choosing urban and commercial development following mining would exclude other land uses almost entirely, and the damage would be permanent. Impacts from increased erosion would occur during construction operations and ambient air quality would be reduced. Increased pollution of local waterways would also occur, and noise levels would be increased.

If there were a need for community expansion to relieve congestion or to increase the quality of life, this option would be attractive.

Multiple Use

Multiple use or a combination of the above alternatives would fit the best features of each to the land's capability.

The selection of post-occupancy land use on the reservation would be a decision of the Crow Tribe and would be based on planning objectives encompassing the least adverse environmental impacts. With respect to private land, ultimate use objectives will have to be developed cooperatively with the land owner. In either case, impacts vary with the objectives chosen.

MINING ALTERNATIVES

Presently the most common method for extracting coal in the State of Montana is strip mining. Two variations of strip mining, open pit and quarry mining, are being used in Wyoming. Coal mined by underground and auger methods cannot compete at present with coal mined by surface mining in the thick western coal seams.

The principal reasons for the growth of strip mining are that (1) full production can be reached quickly; (2) the coal can be mined more economically; (3) a greater percentage of the coal present can be recovered; and (4) strip mining is safer than underground mining.

Since surface mining methods disrupt the land surface, reclamation of strip-mined land is now considered to be an essential part of mining operations. Reclamation can provide improvements to the mined-out land such as increased esthetic value, eventual reuse of the land, and minimization of erosion.

SURFACE MINING

Strip Mining

Stripping is the usual mining method used where the coal seams lie relatively flat and are within 150 to 200 feet of the surface. In 1971, approximately 50 percent of the total U. S. production was from strip mines. Up to 90 percent of the coal bed can be recovered, which makes stripping the most efficient mining method. Strip mining may be accomplished by either area stripping or contour stripping, depending upon the topography of the land to be mined. These methods include the removal of topsoil and rock (overburden) to expose the coal bed, removal of the coal, replacement of the overburden spoil material, and replacement of the topsoil.

Area Strip mining is utilized where the topography is relatively flat and the overburden material thickness is fairly constant. The operation is usually started with a long narrow box cut perpendicular to the direction of mining. The overburden from the box cut is deposited alongside and parallel to the cut, exposing the top of the coal seam. Removal of the coal then follows. Subsequent narrow strips are then cut parallel to the box cut, and the overburden is deposited in the previous cut from which the coal has been removed. Mining may then continue to the limits of the property, or until an uneconomical overburden-to-coal ratio (normally 3 to 1, although ratios up to 5 to 1 may become economical in the future) is reached.

Much of the overburden in the Tongue River coal areas of Montana contains shale and sandstone and must be drilled and blasted before it can be removed by draglines or shovels. Bucket capacities of draglines proposed or operating in Montana range from 14 to 75 cubic yards. When the top of the coal seam is exposed along an excavated strip, it is drilled and blasted, removed with a shovel or front-end loader, loaded into large coal haulers, and transported to the plant processing facilities.

Area strip mining operations are the easiest and most economical to reclaim. Contouring of the spoil banks, replacement of topsoil, and vegetative planting are the main components required in the reclamation program.

Contour strip mining is normally used where the terrain is hilly or mountainous and the coal seam crops out along the sides of the slopes. The mining operation follows the coal seam contour around the hillsides, removing one or more cuts into the hillside until the overburden-to-coal thickness ratio becomes uneconomical. Overburden material is deposited as spoil along the downhill side of the cut, and the last cut forms a highway along the uphill side. The result is a flat bench or shelf along the hillside.

This procedure allows landslides and extensive erosion of the highwall and overburden spoil material to occur. Also, a much greater amount of land is adversely affected than by area strip mining, for the highwall occupies a relatively large percentage of the mined area and the overburden spoils bury essentially productive land.

Methods used to mitigate these adverse effects include leveling the spoil piles to within about seven degrees of the original slope of the ground, or even backfilling and leveling the overburden to the original contours of the slope. The overburden may also be moved in some cases by truck and used to fill a small canyon, leaving a level area.

Auger Mining

Auger mining can be used to supplement the recovery of coal at contour or area strip mining operations after the thickness of overburden becomes excessive. It may also be used where the terrain is so steep that other recovery methods are impractical. An auger is used to bore horizontal holes up to 90 inches in diameter and over 200 feet long into the face of a coal seam exposed in a highwall or hillside. Recovery of coal by this method generally does not exceed 30 percent, for sufficient coal must be left in place to provide support for the overburden. However, land surface subsidence problems may still occur.

Auger-mined land can be reclaimed by sealing the auger holes with impervious material to prevent drainage, and by regrading and revegetation.

Open Pit Mining

Open pit mining involves the removal of coal and overburden from a surface-mined area that increases in size as mining progresses to deeper levels. The method is used where numerous parallel coal seams dip or slope steeply into the ground, rather than in an area of relatively flat-lying seams. The overburden must be removed from the open pit along with the coal.

Reclamation of this type of mine cannot be accomplished until mining ceases, at which time the overburden can be replaced in the open pit. But in some cases, it may not be practicable to return enough overburden material to the mined-out pit, and restoration of the land to a configuration even remotely resembling its former state may not be possible.

Quarry Mining

Quarry mining, a term used by AMAX Coal Company to describe its strip mining operation in a 70-foot coal seam in Wyoming, is used to recover coal averaging over 60 feet in thickness. Benching of the coal seam is used to facilitate removal. The mining plan for overburden removal and replacement in this method results in a land surface lower than the original, but similar in appearance. All spoil material is placed back into the mined area and reclaimed. In an area where the water table is near the surface, the end result might be a lake.

Strip mining has potentially adverse impacts on the natural environment. The enjoyment of hunting, fishing, and allied leisure-time activities can be lessened, and nearby agricultural, residential, commercial and industrial activities can be affected. Strip mining produces more noise and vibrations from blasting, drilling, heavy mining equipment, and trucks than does underground mining. Modification of the habitat, alteration of ground cover and of drainage systems, destruction of land forms, siltation of streams, and destruction of timber and grazing resources may also be quite pronounced. In addition, landslides are more common, though subsidence does not normally occur.

Mitigation or elimination of these impacts can be accomplished by early reclamation and revegetation of the disturbed lands.

UNDERGROUND MINING

It is not likely that coal will be mined by underground methods for many years on the Ceded Area or Crow Reservation because of the abundance of low-cost strippable coal deposits. These coal deposits consist of lenticular seams that may vary markedly in thickness over very short distances; and overburden composition is also quite variable, ranging from soft shales to massive sandstones. Such conditions are somewhat less than ideal for underground mining operations, where a uniform coal seam thickness and competent strata overlying the coal seam are desirable for safe mining. Economical underground mining operations are also dependent on the presence of large, regular blocks of coal which can be mined with available automated machinery.

Underground mining methods are utilized where coal-bearing strata are situated at depths uneconomical for surface mining, that is, when the thickness of the overburden exceeds several hundred feet, or when the overburden-to-coal-seam thickness ratio is greater than 3 to 1.

Development of underground mines requires an expenditure of approximately six times more capital than for the development of a surface mine. Maximum production from a single underground mine is usually limited to from 2,000,000 to 3,000,000 tons annually, whereas a single strip mine operation can produce more than twice this amount. Manpower requirements for underground mines are considerably greater than those for strip mines, and the national manpower productivity of strip mines is approximately three times that of underground mines. Depending on the geographic location and geology, this ratio can increase to as much as fifteen times or more.

Hazardous mining conditions underground are another consideration. Dangers such as roof falls, coal falls, fires, water, explosions, and gas or dust inhalation (black lung disease) are all too common in spite of stringent Federal mining regulations and careful supervision. The fatal and disabling accident rates for underground mining are much greater than for strip mining. In 1972, the fatal accident rate underground was 0.42 per million tons mined, compared to 0.07 per million tons for strip mining. Thus, accident rates for strip mining operations are comparable to those for the construction industries.

Two methods commonly used to extract coal underground are the room-and-pillar and longwall methods. A short discussion of these methods follows:

Room-and-Pillar

This method of underground coal mining has been used the longest in the U.S. There are two variations, conventional and continuous mining: Conventional mining requires that undercutting, drilling, placing of explosives, blasting, loading of coal, and roof bolting be done in separate operations, while continuous mining uses electric-power coal-mining machines that bore, dig, or rip the coal from the working face of the mined seam in one operation. However, these machines are actually operating only about 20 percent of the time to allow for shoring, waits for hauling equipment, servicing of equipment, etc.

Room-and-pillar mining is accomplished by driving into a coal seam from lateral or panel entries which connect to a main corridor. Advancement of mining into the seam leaves a regular system of rooms and pillars where the coal has been excavated or left in place to support the roof of overlying strata. After an adequate block or section of the coal seam has been mined, a portion of the pillars can be recovered during the retreat back to the main entry.

Where the entire thickness of the seam is mined (10 feet, due to available mining equipment), 60 percent or more of the coal in the seam may be recovered under an ambitious program of retreat mining. Oftentimes coal is left as a roof support and as little as 20 percent is recovered. Such would be the case with the thick near-surface coal seams on the Crow Reservation.

Longwall

Underground mining by this method makes extensive use of automatic machinery. Blocks of coal from 300 to 600 feet in width and in some places over a mile long are laid out underground. A coal-shearing machine capable of cutting heights between three to five feet moves back and forth along the working face over the entire width of the coal block. The coal cut from the face falls into conveyors and is transported to the surface. As the block of coal is mined, self-advancing hydraulic jacks support the roof adjacent to the working face, and the roof then caves in behind this area as mining progresses. The percentage of coal recovery with this mining method can exceed 90 percent where the coal seam thickness matches the cutting height capabilities of the machinery. However, this would be a rare occurrence with the thick western coal seams.

Hazards

Subsidence of the ground surface is common above many abandoned and some active underground coal mines. The amount of subsidence is related to the mining method employed, the amount of coal removed, the thickness and depth of the coal bed(s), and the composition and strength of the rock strata overlying the coal. Collapsed areas may intercept or short-circuit both surface and subsurface water moving across or through the subsided area. Locally, subsidence may provide increased communication between aquifers and, in some localities, cause landslides.

With room-and-pillar mining systems, the most successful way to minimize surface subsidence problems is to plan the mining so that enough adequate coal pillars are left unmined; but unfortunately, this procedure results in poor recovery of coal. To achieve as complete a recovery as possible during mining, controlled subsidence is allowed to the point of natural stabilization. Longwall mining systems, which can achieve from 90 to 95 percent recovery, are widely used in Europe, where methods have been developed for controlled subsidence with little environmental damage.

Another hazard of underground mining is mine fires, which may be caused by any of several different problems, such as: (1) an electrical short in underground mine power distribution systems, (2) spontaneous combustion in slack coal deposits resulting from underground mining operations, and (3) explosion of methane gas due to disruption of an electrical system. Under Federal laws, methane gas accumulations must be monitored during underground mining operations, and concentrations of 0.5 percent or greater in mine atmospheric environs are considered excessive. Explosive concentrations in the air range from 5 to 15 percent methane, with 7 percent being the optimum. Federal regulations require the shutdown of mining equipment in the presence of excessive methane gas concentrations in underground mines.

Ground and surface waters entering active underground mine workings are normally pumped to the surface for disposal. In some areas the water becomes acidic by reacting with the pyrite in the coal. Acid mine-water may drain from abandoned mines indefinitely and pollute water supplies downstream. Because of the small amount of sulfur in most of the Crow coal, it is probable that acid mine-water will not be a problem in areas of large-scale mining.

Appreciable volumes of waste may be generated from underground coal mining and coal processing activities. The volume of waste depends on the thickness and characteristics of adjacent and in-seam strata, geologic structure, and amount of rock that must be moved. The type and volume of waste from processing depends upon the uses for which the coal is being prepared, the characteristics and amounts of impurities in the coal, and the efficiency of processing equipment.

Uncontrolled disposal of mining and processing wastes constitutes a major source of pollutants. Water flowing over disposal areas transports silt and leached minerals to adjacent drainage areas, and the cumulative effect can be severe. Dust-size particles transported by winds contaminate adjacent land and water. Both problems have long-term undesirable effects.

Waste disposal areas require a commitment of land resources and, if poorly constructed and uncontrolled, present an unattractive appearance. Slides and slumps occur where waste is deposited on steep slopes and where moisture and clay minerals act as lubricants. Large quantities of waste can move downslope and inundate nearby land or block streams. Slides are hazardous to residents, visitors, and animals.

In the past, mining and processing wastes have contributed large volumes of sediment to nearby streams and have also been sources of air pollution. The most commonly used current technique for preventing widespread scattering of waste is to compact it in layers, seal with incombustible soil, and establish vegetation to help prevent infiltration of surface water and minimize erosion.

Mine and coal-processing waste may be returned to abandoned underground workings for disposal. This is currently being done in some areas to control surface subsidence.

Many surface operations associated with underground mining cause dust problems, such as the use of mine-access roads, coal handling, and coal processing. These problems may be minimized by the installation of proper physical plant equipment and by certain operational procedures.

Environmental impacts from underground mining operations, particularly after mine closure, are caused by waste disposal areas, unsealed abandoned mine openings, and abandoned mine buildings and structures. Other impacts include those associated with drilling, blasting, mine fires, surface subsidence, alteration of ground water hydrology, product processing, effluent discharges, and accidents. These latter impacts are more severe in underground mining operations than in surface mining.

POTENTIAL FUTURE EXTRACTION METHODS

Technology is being developed for several advanced methods of removing coal or coal derivatives from underground coal deposits without extensive access to the coal seam itself. Removal of the coal in a solid, liquid, or gaseous state is being researched as discussed below:

(1) Solid - The use of remotely controlled, completely automated underground equipment is one method that might be utilized. Another is the fracturing of the coal seams underground and hydraulic flushing of the coal to the surface.

(2) Liquid - Other possibilities include electrical pyrolysis of the coal underground to liberate volatile liquids and gases, or dissolving with organic solvents.

(3) Gas - Hydrogenation of the coal directly into methane gas through the use of high temperatures and pressures is being studied. combustion through a partial oxidation of the carbon content of coal to carbon monoxide is a simpler means of underground gasification.

Should any of these processes ever become feasible, the level of energy recovery and the amount of surface subsidence would probably be highly unpredictable.

COAL USE ALTERNATIVES

The low sulfur content and relatively low heating properties of the coal underlying the Crow coal resource area indicates that the most economically feasible energy-producing uses to which the coal may be put are generation of electricity, gasification, and liquefaction. Rather than shipping the coal great distances, developers could build such plants adjacent to the mine. However, in view of environmental considerations, shipment of the coal to energy-consuming locations would have fewer adverse impacts on the Crow Indian Reservation and southeastern Montana in general. The impact of construction and operation of these complex industrial facilities on the surrounding physical and social environments would be pronounced. Discussion of the processes and plant installations for these coal use alternatives follows.

POWER GENERATION

Power generating facilities require a relatively close proximity to large supplies of coal and water, and an efficient means of distributing the power to a consumer market.

Transportation and fuel costs for on-site electric power generation would be minimal. However, a coal-burning electrical power generation plant would have to be constructed, transmission lines would have to be built, and the generating plant would have to be connected into the existing power distribution network.

Water rights and large volumes of water would have to be obtained, and pipelines and storage facilities would have to be built to supply an on-site steam-generating plant.

The local environmental impacts resulting from on-site power generation would be (1) degradation of air quality by stack emissions, (2) land use problems related to ash disposal, (3) noise from the installations, (4) diversion of large quantities of water from other uses, (5) esthetic degradation, (6) dust problems, (7) loss of land used by the facilities, and (8) increased employment and related economic benefits. Impacts associated with mining and reclamation would remain the same.

With present-day technology, two essentially different types of steam turbine plants are feasible for electrical power generation from coal. Conventional steam turbine power plants burn coal in the solid state for fuel, and the recently developed combined-cycle gasturbine and steam turbine power-generating plants utilize low-Btu power gas from an associated gasification plant. In the 1980's and 1990's, magnetohydrodynamics (MHD) will probably be added to power generation facilities. These plant configurations are described in the following section:

Conventional

Steam turbine power-generating plants may be constructed at mine-mouth sites, or in the area of consumptive use which may be far removed.

The process of converting coal to electrical energy by conventional steam turbine generating plants is relatively standardized. Finely pulverized coal mixed with air is fed into a furnace and ignited. Energy from the combustion process, in the form of heat, is transferred to water in a power boiler and is then converted into high-pressure steam. The steam is sent to a turbine where energy obtained from the expansion of steam is used to drive an electrical generator. The electrical transmission system then distributes the generated power to marketing areas.(2) Extra-high-voltage (EHV) and ultra-high-voltage (UHV) powerline transmission grids are required for transporting this power.

The thermal efficiency of conventional power plants ranges from about 30 percent for older plants to as high as 40 percent for the more recent installations.

The main by-products of this process are waste heat from conversion of low-pressure steam to water; and slag, fly ash, sulfur dioxide gas, and other chemical and heavy metal contaminants. Flow-through systems, evaporative cooling towers, or dry-cooling facilities may be utilized to dissipate the waste heat.

Single- or double-pass flow-through power plant cooling systems would require about 400 to 600 acre-feet of water annually for each megawatt of plant capacity.(44) The water discharged from a system of this type would be essentially equal to that recieved by the plant, less consumption for blowdown and makeup water. However, the water would be subjected to an 11° to 17° F rise in temperature, which could cause thermal pollution of the receiving stream.(46)

Evaporative cooling towers would require much less cooling water, on the order of 10 to 15 acre-feet annually for each megawatt of plant capacity.(44) This water would be completely evaporated and lost for other uses, and additional blowdown and makeup water would be required.

Dry cooling tower facilities constructed at conventional power generating facilities would not require water for cooling; however, the capital cost is much higher and the facilities much more extensive than for an evaporative system. The technology for this type of cooling system is still under development.

Complex precipitators or flue gas scrubbers are required to remove the particulate and gaseous combustion by-products from the plant stack gases. The most advanced equipment presently available for this purpose is capable of removing as much as 99 percent of the particulate matter. However, due to the vast quantities of coal utilized, even this small particulate residual amounts to an enormous atmospheric pollution load.

Removal of gaseous by-products such as sulfur dioxide at the high rates attained for particulates is not possible with present technology. Today, it is possible to remove 50 percent or more of the sulfur dioxide. Removal levels for other contaminants such as fluorine and heavy metals are considerably higher than for the gaseous by-products.(49) (50) Adequate treatment and/or disposal facilities for these contaminants must be provided to guard against land and water pollution.

Power Gas

The technology for a combined-cycle power plant, utilizing low-Btu power gas derived from coal, has only recently been brought to the point where full-scale commercial plants are being considered. It is anticipated that they will be coming on line around 1980, and their advantages over a conventional plant will include increased thermal efficiency, greatly reduced emission of pollutants to the atmosphere, reduced cooling-water consumption, shorter lead times, and lower capital and operating costs. It is probable that once the cost of constructing and running one of these plants on a commercial scale is fully detailed, conventional steam-turbine plants will no longer be considered the most feasible type of power generation.

The combined-cycle process consists of three parts: (1) the gasification of coal to low-Btu power gas having heating value of 120 to 160 Btu/scf, (2) burning of the fuel in gas turbine to produce power, and (3) utilization of the hot waste exhaust gases from the gas turbine as fuel for heating the power boiler of a steam-turbine.

The basic gasification process for convertin coal to a low-heat-value power gas consisting of carbon monoxide, hydrogen, and nitrogen has been well demonstrated. In this process the coal is supplied with an amount of oxygen in the form of air which will prevent the complete combustion to carbon dioxide and water. A pressure vessel or reactor operating at 10 to 20 atmosphere is used to accomplish this conversion. There are four basic sequential reactions in this gasification process:

Oxidation - This heat-producing reaction results when the oxygen (in the air or from a pure source) reacts with the coal to form carbon dioxide and water (steam):

$$C + O_2 \longrightarrow CO_2$$

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Gasification - In this reaction heat is absorbed when unburned carbon from the coal reacts with steam and carbon dioxide to form hydrogen and carbon monoxide:

$$C + \left(\begin{matrix} H_2O \\ CO_2 \end{matrix} \right) \longrightarrow CO + \left(\begin{matrix} H_2 \\ CO \end{matrix} \right)$$

Hydrogasification - The hydrogen formed by gasification reacts with carbon from the coal to form small quantities of methane:

$$C + 2H_2 \longrightarrow CH_4$$

Devolatilization - Devolatilization of the coal also occurs when it is heated, forming char and hydrocarbons:

$$\text{Coal} + \text{Heat} \longrightarrow C + CH_4 + HC$$

These basic reactions can occur simultaneously or may be separated within a reactor. The heat required for the gasification reaction is normally matched by the release of heat from the other reactions. The composition of the power gas produced depends on the nature of the coal and the temperature, pressure and gas formed in the gasifier. A gas mixture with a heating value of somewhere between 120 and 160 Btu/scf is obtained from air-blown gasifiers.(51)

The main purpose in producing power gas from coal is to contain the ash, sulfur and other contaminants within the plant for easy processing and environmentally safe disposal. The conversion of conventional plants to utilize power gas may be more economical than the addition of complex air pollution control equipment for emissions control. Negligible amounts of pollutants are released to the atmosphere in the manufacture of power gas: reduction of about 90 percent in sulfur dioxide, almost 100 percent of the particulates, and significant percentages of nitrogen oxides are anticipated.(43) Water treatment facilities for the small quantities of contaminants generated in the gasification, particulate-scrubber and sulfur-removal equipment are necessary components of the gasification plant.

Basically, two types of pressurized gasifier plants may be utilized: the fixed-bed and fluidized-bed configurations with appurtenant treatment facilities. The fixed-bed type plant configuration has been in use in its basic form, the Lurgi process, since 1936, and variations of it are now being investigated. The technology for fluidized-bed gasifiers is presently being developed. Various gasifier reactor plant configurations are discussed in the following section on gasification.

The low-heat-value power gas from the gasification plant can be fed either to a power boiler in a conventional steam turbine plant or to a combined-cycle gas turbine-steam turbine system for power generation. The efficiency of the conventional system is somewhat lower than that of the combined cycle due to losses in the power boiler and gasification system, and in energy uses for furnishing process steam and feedwater. The overall thermal efficiency of the combined cycle will probably range from near 40 to around 50 percent, increasing as more sophisticated gasification and gas turbine technology is developed.(44) For example, the technology of present-day aircraft-type gas turbine engines could be applied to the development of a gas turbine system for power generation. The steam turbine section of a combined-cycle plant would be similar to that presently utilized for conventional plants.

At the present level of cooling technology, waste heat from the steam turbine section of the combined-cycle plant must be dissipated through consumptive use of water. Water is also required for the particulate scrubber and other sections of the gasification plant. A comparison of the typical consumptive water use requirements in acre-feet per year for several variations of a conventional plant and a combined-cycle plant is shown in Table 31. (43)

Table 31 Consumptive Water Use Requirements

System	Condenser Cooling*	Stack-gas scrubbing/ Coal Gasification	Total water use in AF/YR per Megawatt
Conventional Plant (Coal-Fired)	11.5	0	11.5
Conventional Plant (with Wet SO_2 Scrubbing)	11.0	4.8	15.8
Conventional Plant (with Coal Gasification)	12.6	6.0	18.6
Combined-Cycle Plant (with Coal Gasification)	7.1	5.2	12.3

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* Utilizing evaporative cooling towers

If reduction of conventional power plant emissions will be required at all future power generating installations, the combined-cycle plant is probably the best choice presently available as far as consumptive cooling-water use requirements are concerned. Flow-through cooling-water systems and dry cooling towers could also be utilized to dissipate the lesser amount of waste heat from a combined-cycle plant.

Magnetohydrodynamics (MHD)

The basic concept for MHD was established in the early 1880's by Michael Faraday, and patents on the process were issued in the early 1900's. Significant progress in refining the process was made during the later 1950's and early 1960's, but additional research is needed before a full-scale plant can be constructed.

The MHD electrical power generation process basically involves the passing of a hot ionized gas or liquid metal vapor (conducting fluid) through a magnetic field. MHD is more efficient than the conventional steam turbine or combined-cycle power generation processes, because it combines into one step all of the existing steps required (from heat to mechanical force to electrical power) to convert coal or petroleum fuels into electrical energy. In essence, it is a heat engine that combines the function of both a conventional turbine and an electrical generator. MHD is generally thought of as a topping cycle for steam turbine or gas turbine cycles, the waste heat energy from MHD being used to power these cycles. Overall efficiency from this type of plant would be in the range of 50 to 60 percent.

Several variations of the MHD process are available:

Open-Cycle Gas MHD - This is the most developed cycle, in which the working fluid or plasma is a seeded gaseous combustion product. Powdered coal or other fossil fuel is mixed with preheated and/or oxygen-enriched compressed air and burned at temperatures of 4,000° to 5,000°F. The hot gases are then seeded with cesium or potassium (to increase electrical conductivity of the gas) and accelerated through a nozzle at supersonic speed. A superconducting magnet surrounding the nozzle causes the hot gases (plasma) to become the "armature" of a direct current generator. Electrical current generated is then extracted by electrodes, converted to alternating current, and fed into a power transmission grid.

The heat transfer and mechanical efficiency factors, which limit conventional power plant efficiencies, are minimized or eliminated. Thus overall thermal efficiencies as high as 60 percent can be attained with the open-cycle system.

Closed-Cycle Gas MHD - This is a similar process which is designed to operate at lower temperatures (3,000° to 3,500° F). It utilizes as a working fluid seeded noble gases such as helium in a closed system. These are externally heated by fossil fuel combustion or a high-temperature nuclear reactor.

Closed-Cycle Liquid Metal MHD - This variation of the MHD process will operate at even lower temperatures (1,500° to 3,000° F). Heat energy supplied by fossil or nuclear fuels is utilized to vaporize the liquid metal before it is accelerated through the magnetic field. Efficiencies are slightly reduced with this cycle.

Technological problems involving the metallurgical life of equipment materials in the "generator" are encountered with open-cycle MHD due to corrosion, erosion, and ash or other deposits. Although these problems are less acute with the closed-cycle MHD systems, the systems are subject to other technological problems.

The highly efficient MHD generates less waste heat, reducing (by a factor of 1/3 or 1/2) the amount of cooling water necessary for heat dissipation with steam bottoming cycles. Thermal pollution or consumptive use of water supplies is drastically reduced, or could be eliminated altogether if a gas turbine bottoming cycle is utilized.

Since [process] economics requires that a 99 percent or higher recovery of metal seed material be achieved, the use of high-efficiency electrostatic precipitators and other pollution control devices is necessary. Close operational control of these devices will assure low atmospheric pollutant emission levels. (2)

Several practical applications of MHD to power-generating systems are the peaking plant, base-load hybrid plant and the multi-product MHD associated plant. (52) The peaking plant is probably the simplest of these and would provide supplemental power to an electrical distribution system only during emergency or peak load periods. The base load for such a system would probably be supplied from a network of conventional or combined-cycle fossil fuel plants and from nuclear power plants. The economic requirements for this type of power are low capital cost, with high efficiency being less important. Rapid start-up, shutdown and on-line availability are also essential, and maintenance and personnel costs must be low. A typical installation could consist of a rocket combustion chamber in conjunction with an MHD generator. Capital costs of such a system would be low, but operating cost could be excessive (except for emergency operation) due to low thermal efficiency, and the high cost of fuel (liquid oxygen) and seed material.

A base-load hybrid MHD plant is the most favorable configuration for the immediate future. The high efficiency of a combined MHD cycle has been documented by many studies and will soon become a reality since a 75 MW pilot plant is being constructed near Moscow, Russia. It is anticipated that coal-fired combined open-cycle MHD/conventional regenerative steam turbine-cycle plants will be coming on line during the 1980's. Assuming that combined MHD-cycle base=load plants operate at an annual capacity of 80 percent, the overall thermal efficiency is calculated to be about 50 percent. As technology improves, the thermal efficiency of these plants should improve to around 60 percent by the 1990's. Results of cost of power generation studies indicate that mine-mouth base=load MHD is the most economical process over all competitors, including nuclear-fueled generation.

An associated multi-product plant is conceivable in that the low-cost energy available from MHD power plants, the already available coal, air, water and product gases, as well as additional chemical raw materials, could be brought together to furnish numerous chemical and industrial products. With the proper selection of a set of highly interrelated products manufactured under one roof, the economics could be extremely attractive.

Gasification

It is anticiapted that the dwindling reserves of natural gas in the U. S., combined with the high cost of LNG imports and heavy demand for clean fuels from many sectors of the economy, will make the gasification of coal into synthetic natural gas (SNG) an economically feasible process in the near future. The SNG product will be very comparable to natural gas and will contain a minimum of about 950 Btu's per cubic foot.

The rate of growth of a coal gasification industry will be affected by availability of coal and petroleum feedstocks, development of required mining capacity, availability of water, availability of capital, and availability of refining capacity to provide light hydrocarbon for feedstocks.

The Department of the Interior gives the following forecasts for the production of synthetic gas:

Table 32 Estimated Production of Synthetic Gas

	Total Gas Produced		Energy Inputs	
Year	Billions of cubic feet	Trillions of Btu	Coal, millions of tons	Petroleum, millions of barrels
1980	700	700	19	84
1985	2,000	2,000	86	128
2000	5,500	5,500	308	105

Projections of the Interior Department for the development of the coal gasification industry estimate a yearly production of coal gas by 1980 at 700 billion cubic feet. None is produced currently.

The two basic approaches for conversion of coal to high Btu pipeline gas are: (2)

(1) The indirect approach, whereby a synthesis gas (400 to 500 Btu's per cubic foot) is formed by partial combustion of coal with pure oxygen, or by the reaction of coal with steam; after which the gas is cleaned and catalytically methanated to produce a high-methane-content gas.

(2) The direct approach which involves the direct reaction of hydrogen with coal to form methane gas. This approach bypasses the oxidation and gasification reaction phases discussed previously under the section on power gas.

In the indirect approach, the initial gasification process is essentially the same as that used in the production of power gas which was discussed previously. To upgrade this gas to match the methane content and heat value of natural gas requires additional processing that is relatively expensive. First the oxidation reaction must be fed pure oxygen rather than air to produce a higher Btu content synthetic gas that is not diluted with nitrogen. Second, additional hydrogen must be produced and reacted chemically with carbon monoxide to form methane. This can be accomplished by a two-step reaction. (51)

Additional hydrogen is produced by injecting steam to react with carbon monoxide:

$$H_2O + CO \longrightarrow H_2 + CO_2$$

The hydrogen produced is then made to react with carbon monoxide to generate methane:

$$3H_2 + CO \longrightarrow CH_4 + H_2O$$

In general, pipeline gas processes employ either pure oxygen or hydrogen with steam at pressures ranging from 30 to 60 atmospheres to produce a high-methane-content gas. A comparison of the fuel gas properties required for both pipeline gas and power gas is shown below: (51)

Table 33 Fuel Gas Properties Required

	Pipeline Gas	Power Gas
Heat Content (Btu/scf)	± 1,000	+ 120
Pressure (atm.)	+ 30	10-20
Temperature, °F	± 70	70-1800
Composition	CH_4	CO, H_2, N_2, CO_2, H_2O, CH_4
Cleanliness/Sulfur	1 ppm	± 550 ppm or 1.2 lb $SO_2/10^6$ Btu
Particulates	0.01 lb/10^6 Btu	0.1 lb/10^6 Btu

Presently about 65 different coal gasification processes are known, but none is able to produce gas at the price competitive with recent natural gas prices in the United States. The following discussion will center on six of these processes which are either available for commercial use or are in the pilot plant stage of development. (53)

Lurgi Process

The Lurgi gasification process is the oldest commercially available and has been proven in synthesis gas plants. The process uses a fixed-bed gasifier unti which requires pretreatment of coking coals.

The present process consists of six steps in the production of synthesis gas from coal:

1. Pressure gasification or formation of a crude contaminated gas.
2. Shift Conversion - The adjustment of the H_2/CO ratio to facilitate subsequent reactions.
3. Rectisol gas purification - An organic solvent absorption process to remove impurities.
4. Methane synthesis - Conversion of carbon monoxide and hydrogen components of the gas to methane.
5. Gas liquor treatment - Removal of phenols and ammonia.
6. Drying of the product gas.

Methane synthesis to the point of comparability with natural gas has not been proven commercially, although bench-scale tests have indicated it is possible to produce a gas with a heat value of 970 Btu/scf. The overall efficiency of the process is about 68 to 70 percent. The first commercial-scale test of production of pipeline SNG from coal will be undertaken by Conoco Methanation Company, which will add methanation facilities to the Scottish Gas Board's Lurgi-process Westfield coal gasification plant.

Standard Lurgi gasifier-reactor units are about 12 feet in diameter and produce about 350,000 ft^3/hr of gas. They are of fixed-bed design and can handle coking grade coals.

El Paso Natural Gas Co. has announced plans for construction of a 250 million cfd pipeline gasification plant in northwestern New Mexico using the Lurgi process. Plans call for plant startup in 1976 and production in 1977.

Texas Eastern Transmission Corp., Utah International Inc., and Pacific Lighting Corp., a consortium, also hope to be operating a 250 million cfd plant in 1975.

Koppers-Totzek Process

The Koppers-Totzek process, marketed by Heinrich Koppers Gmbh in Germany, has been in commercial operation since 1952 and has been used mainly to produce a synthesis gas for ammonia production. Production of pipeline-quality gas with this system has not been proven commercially, although the process is being offered for use in this field. The Koppers-Totzek process would consist of the following steps in the production of pipeline gas.

1. A raw synthesis gas is formed by the reaction of coal with steam and oxygen.
2. The gas is cooled and particulate matter is removed.
3. Acid gases produced are removed.
4. Shift conversion of the H_2/CO ratio facilitates subsequent reactions.
5. Methanation of the synthesis gas then follows, along with drying of the product gas.

The reaction temperatures in the gasifier are on the order of 2,700° F, which means that the raw synthesis gas is free of condensable organic compounds. Therefore, potential gaseous or liquid pollutants such as ammonia or phenols are not produced.

HYGAS Programs

The HYGAS pilot plant programs conducted by the Institute of Gas Technology are the furthest advanced of the programs being developed in the United States. The research is being financed by the Office of Coal Research and the American Gas Association. Two separate processes have been developed.

One of the processes is the direct hydrogenation of pretreated coal. The process consists of the following steps:

1. Coal is pretreated at elevated temperatures with an oxygen-bearing gas to destroy its coking tendency.
2. The coal is then fed into a fluidized-bed reactor maintained at a temperature and pressure of 1,300° to 1,500° F and 1,000 to 1,500 psi respectively.
3. Hydrogen is then injected into the reactor to maintain the powdered coal in a fluid-like condition and to react with it to produce methane.

The pilot plant program for this process calls for initial operation of the hydrogasifier with hydrogen from a package plant. This phase has been tested already. The second phase of operation will integrate the hydrogasifier with an electrothermal gasifier, eliminating the need for a package hydrogen plant. Testing of this phase should be completed in 1974.

1. The second process developed consists of the following steps:
2. Gasification of powdered coal in suspension with oxygen and steam produces a mixture of carbon monoxide and hydrogen.

The synthesis gas mixture is then upgraded to pipeline quality by catalytic methanation with a nickel catalyst.

Pilot plant construction for this phase should be completed in 1974.

CO_2 Acceptor Process

Consolidation Coal Co., under contract to the Office of Coal Research and Stearns-Roger Corp., has constructed and is operating a demonstration plant using this process.

The process is unique in that it utilizes lignite in conjunction with calcined dolomite on a 1:2 weight basis to produce a 375 Btu/scf synthesis gas. The generalized steps required in the gasification process are:

1. Calcined dolomite is circulated through a fluidized bed of lignite or sub-bituminous coal char.
2. Reaction of the dolomite with carbon dioxide, one of the gasification reaction products, liberates sufficient heat to sustain the endothermic carbon-steam reaction.

This results in a product gas enriched in methane and hydrogen. Methanation facilities for upgrading the synthesis gas to pipeline quality were not constructed; however, this type of equipment is being tested at other gasification facilities.

The CO_2 acceptor process is limited to the utilization of low-grade western coals (lignite and sub-bituminous) that will gasify at low temperatures. It is considered to be one of the more promising gasification processes, and construction of a commercial plant is presently projected for the 1974-1976 period.

BI-GAS Process

Bituminous Coal Research, Inc. (Affiliate of the National Coal Association) has prime responsibility for this project. The Office of Coal Research and American Gas Association are funding the project. Stearns-Roger Corp. will complete construction in 1974 and begin a three-year operation of the pilot plant.

The BI-GAS process uses an entrained bed two-stage gasifier rather than a fixed or fluidized-bed configuration. The process can use all types of coal without pretreatment. A main objective in testing this process is to optimize the operating variables of temperature, pressure, and residence time for maximum (high-yield) methane formation in the second stage of the gasifier.

Development of a pipeline gas methanization system based on a fluidized-bed catalytic reactor process is proposed. Pending initial results of the pilot plant testing program, construction of a commercial plant may begin in 1975-1976.

Synthane Process

A pilot plant has been designed for this process. The Bureau of Mines developed the process, which will convert all types of coal to pipeline-quality gas.

The process consists of the following steps:

1. Pretreatment of the coal to eliminate adverse coking properties.
2. Carbonization and steam-oxygen gasification of the coal in a fluidized bed.
3. Shift conversion of synthesis gas and purification.
4. Catalytic methanization.

Operation of the pilot plant is scheduled for 1974.

A number of other processes of various configurations have been tested under bench-scale conditions, and evalution of them will be required to determine the most practicable and economic ones. However, the incentive for development of economic coal gasification processes will probably continue to increase in the future, and it is anticipated coal gasification plants will be operational by the late 1970's or early 1980's.

It is not anticipated major air or water pollution problems will be encountered with these gasification plants, due to the sophisticated process equipment required for cleaning the synthesis gases, and the installation of water treatment equipment for processing of plant waste effluent streams.

Typical water consumption figures for a 250 million cubic foot per day commercial coal gasification plant producing pipeline-quality gas are shown as follows: (44)

Table 34 Water Consumption for 250 Million Cubic Foot Per Day Plant

Cooling Device	Water Consumption AF/yr.
Evaporative Tower	17,700
Dry Tower	6,000

The basic gasification and treatment processes would consume about 6,000 acre-feet per year for this size plant. Savings in water consumption could be obtained only by eliminating evaporative cooling towers.

The volume of coal consumed in a 250 million SCF/day gasification plant would amount to about 5,000,000 tons annually.

LIQUEFACTION

Liquefaction of coal for the purpose of obtaining synthetic crude oil and other petroleum products is proposed as a future supplement to the conventional petroleum industry by the mid 1980's. Until recently the development rate of conversion processes for changing coal to clean-burning oil has not been comparable to that for coal gasification. One of the reasons has been the ready availability of imported crude oil at a cheaper price than synthetic crude. As technology is developed and refined, synthetic fuels should become more competitive. Petroleum fuels are susceptible to price escalation due to increased exploration and development costs as well as higher cost of imports.

Development of several synthetic crude oil sources such as oil shale, tar sands and coal will probably occur in the near future. Although coal has an advantage from the standpoint of waste disposal problems, the synthetic crude produced cannot always be processed in a conventional refinery without process modifications.

Several different processes are available for the liquefaction of coal to synthetic crude or tars. These processes are dependent on which types of operations are performed, namely:

(1) Direct hydrogenation of coal.
(2) Extraction of solubles from coal and hydrogenation of the extract.
(3) Distillation of hydrocarbons from coal and hydrogenation of the tar.
(4) Gasification of coal and Fischer-Tropsch hydrocarbon synthesis.[1/]

All of these operations have been performed on a large scale in various chemical processing plants, except the hydrogenation of a coal extract. A comparison of the oil yield and hydrogen requirements for these processes is shown below: (54)

Table 35 Oil Yield and Hydrogen Requirements

Process	Oil Yield lbs/short ton of coal	H_2 Requirements Scf/lb of product
Hydrogenation	1060 - 1220	27 - 35
Extraction + Hydrogenation	780	23
Distillation + Hydrogenation	300 - 460	9 - 16
Gasification + F-T Synthesis	700	0

[1/] Oxygen required for synthesis gas production.

The direct hydrogenation of coal results in a high yield of oil and high consumption of hydrogen. This is because coal contains more oxygen than tar and the carbon/hydrogen ratio of 13:18 in coal is much higher and less desirable than the C/H ratio of 8:12 in tar. Since consumption of hydrogen accounts for a significant part of the production cost, the high consumption-to-yield ratio is important.

Extraction has about the same advantages and disadvantages as the direct hydrogenation of coal. This process differs from direct hydrogenation in that the extract is filtered to remove ash and other insoluble constituents before hydrogenation, allowing a clean product to be obtained. The impurities are passed through the reactor in the direct hydrogenation process and must be separated from the product.

Distillation (pyrolysis) of the coal and hydrogenation of the tar results in lower oil yield and hydrogen consumption. This is because a large amount of the low-hydrogen carbonaceous matter (char) is separated before the hydrogenation step. While this char is used to produce hydrogen in the previous processes, with this process it may be utilized as fuel for a conventional power plant.

Gasification and Fischer-Tropsch hydrocarbon synthesis differs greatly from the other processes. A medium oil yield and consumption of oxygen (instead of hydrogen) for gas production is required. The end products are of high purity and are well suited for subsequent refining processes.

During the past decade, major advances have been made in the development of coal liquefaction processes. The economics of the processes may soon approach that of the conventional petroleum industry.

Several of the more promising pilot plant coal liquefaction-process developments, which have been supported by the Office of Coal Research, are briefly described in the following paragraphs.(55)

Project COED

The char-oil-energy-development process has been under development since 1962 by FMC Corp. The process converts coal to synthetic crude oil, gas, and char by utilizing fluidized-bed pyrolysis and subsequent hydrogenation of the coal oil. A typical plant might consist of four fluidized-bed stages, each operating at a successively higher temperature. From each of these reactors, the volatile products released are passed to a system for recovery of the oil and cooling of the gases.

The oil is then filtered to remove solids and is hydrogenated in a catalytic reactor to remove sulfur, nitrogen, and oxygen. The final product consists of synthetic crude oil ready for refining.

Solvent-Refined Coal

This process was first studied in 1962 by the Spencer Chemical Co. Subsequently the Gulf Oil Co. acquired this company and reassigned the project to the Pittsburgh and Midway Coal Mining Company. A pilot plant is to be erected soon at Fort Lewis, Washington.

In this process the coal is first dissolved in a heavy aromatic solvent (extraction) under moderate hydrogen pressure. The solution is filtered to remove impure solids and then fractionated to recover the solvent. Small quantities of gases and light oils are produced in conjunction with the main product, a heavy organic material (solvent-refined coal). This material has a melting point of about 350° F and contains about 0.1 percent ash and less than one percent sulfur.

All of the inorganic and about 60 to 70 percent of the organic sulfur content of the coal is removed by the process. SRC has a heating value of about 16,000 Btu per pound, making it an ideal clean fuel. Research and development on this process is being concentrated on the utilization of the SRC product and on removal of sulfur and nitrogen from coal-derived liquids.

Chem System, Inc., has also studied a conceptual COG (coal-oil-gas) refinery which would produce synthetic crude oil, pipeline gas, liquefied petroleum gas and solvent-refined coal. The economics of this type of sytem seem quite favorable.

CSF Process

The Consol Synthetic Fuels Process was originally conceived from research conducted during the late 1940's and early 1950's by the Consolidation Coal Co. Bench-scale tests were carried out in the late 1950's and early 1960's. In 1963, the Office of Coal Research initiated the Project Gasoline Program to accelerate CSF process development.

The CSF process uses coal extraction (the conversion of coal into extract and by-product char and gas) to produce an ashless extract that can be hydrogenated to a synthetic crude. The hydrogen is obtained from a hydrogen donor solvent rather than by the addition of pure hydrogen as in the hydrogenation stage of the SRC method. Operating conditions employed are less severe, allowing lower pressure and temperature. The synthetic crude can then be processed to gasoline or other petroleum products using conventional petroleum technology.(56)

H-Coal Process

This process is a development of the Hydrocarbon Research, Inc. H-oil process. It is based on the use of a cobalt-nickel-molybdenum catalyst in ebullating (agitating) bed reactors to hydrogenate coal-oil slurries directly. Bench-scale tests and economic analyses indicate an attractive economic potential.(56)

The only process not presently being investigated by the Office of Coal Research is the Fischer-Tropsch hydrocarbon synthesis. This type of process has already been used in the western world to produce oil from coal on a commercial basis. It utilizes the pressure-gasification of coal in conjunction with synthesis of the gas to crude oil by the use of fixed-bed catalysts. A Lurgi or other reactor can be used to produce the synthesis gas. However, the process plant has a high capital cost, and large amounts of water are formed by the reaction of the synthesis gas.

Consumptive use of water for a 100,000-bbl/day capacity commercial coal liquefaction plant with dry cooling towers would be approximately 10,000 acre-feet per year. Coal volume consumed in a plant of this capacity would be about 10,000,000 tons per year.(44)

LAND, WATER AND AIR USE

Coal-Related Power and Fuels Industries

Land use for coal-related power and fuels industrial developments would not be excessive unless cooling ponds or dry cooling towers are used to dissipate the waste heat from power-generating plants. Otherwise a typical large-capacity power plant installation could be anticipated to occupy space similar to that occupied by the Montana Power Company generating plant at Colstrip. Plant facilities and amount of land used for gasification and liquefaction plants might approximate a large-scale petroleum refinery operation.

Water use alternatives for an industrial complex such as the one envisioned by this statement would have an important bearing on the industrial development potential and availability of water for other uses. The following table shows the relative amounts of water required for various power generation and fuels plant configurations. These amounts are given in terms of a conventional 1,000 megawatt steam turbine generating plant requiring about 11,500 acre-feet of water annually for cooling with evaporative towers.(44)

Table 36 Water Requirements for Alternative Plant Types

Plant Type and Period of Development	Cooling Device	Relative Cooling Water Use in terms of a 1,000 MW Power Plant
Conventional Steam; 1970-80	Single Pass Water Cooling (20° F rise)	50 times
Conventional Steam; 1970-80	Double Pass Water Cooling (20° F rise)	40 times
Conventional Steam; 1970-80	Evaporative Tower	1
Conventional Steam: 1970-80	Dry Tower	Negligible
Combined Cycle: 1980-90	Evaporative Tower	0.65 times
Combined Cycle; 1980-90	Dry Tower	Negligible
MHD-Steam; 1980	Evaporative Tower	0.65 Times
MHD-Steam; 1990	"	0.45 times
MHD-Gas Turbine; 1995	None	Negligible
Coal Gasification; 1980 (250 million Ft^3/day)	Evaporative Tower	1.55 times
" 1980	Dry Tower	0.5 times
Coal Liquefaction; 1985 (100 thousand bbl/day)	Dry Tower	0.85 times

It can be seen from the above that flow-through cooling systems would require very large rivers or lakes to be practical. This limits the use of these cooling systems to areas of relatively high precipitation where the supply of surface water is almost unlimited. For most other areas, the use of dry cooling towers would appreciably reduce the plant water requirements. However, dry cooling towers for large-magnitude power-generating and other complexes are still being perfected technologically. The expense of these facilities with present-day technology would be approximately six times that required for a plant with an evaporative cooling system. To make this type of cooling system economically attractive, the expense of the facilities required will either have to be reduced, or the cost of water used for evaporative cooling purposes will have to increase drastically.

Plant operation, consisting of handling and transporting the coal to the processing unit and converting the coal to electricity, gas and/or crude oil, will involve burning coal or devolatilized coal (char) to generate steam and power or to make hydrogen. Major emissions or waste products that must be controlled are sulfur and nitrogen oxides, bottom ash, slag, and fly-ash. Where coal-conversion plants are located near strip mines, ash and slag from the conversion processes may be returned to the open cuts, and the ground restored in accordance with environmental considerations. The technology for controlling sulfur and nitrogen oxides from coal-burning plants is under continuous development.

The following estimates are given to illustrate the relative magnitude of the major emissions that would have to be handled in a commercial coal-to-pipeline gas plant. The emissions are estimated for a plant producing 250 million cubic feet per day of pipeline gas from coal having 3.7 percent sulfur and 10 percent ash. Such an SNG plant would produce the equivalent Btu energy of 40,000 barrels per day of crude petroleum.

Table 37 Emissions from a 250 Cubic Feet Per Day Plant

Emission	Amount, long tons per day
Sulfur (mainly as hydrogen sulfide)	300-450
Ammonia	100-150
Phenols	10- 70
Benzene	50-300
Oil and Tars	trace to 400
Ash	1,500

Environmental Factors

The use of the coal in power generation, coal gasification, and liquefaction would have a massive impact on the area, far exceeding that of coal mining. Although these uses would have greater beneficial economic impact, their environmental costs may more than overshadow their benefits. Other coal-using industrial plants lying outside the Ceded Area and Crow Indian Reservation will likely add further to the environmental costs.

It might be appropriate to again mention three of the greatest impacts such plants would have. First, any of the three processes would tend to change a rural area into one that is at least moderately industrial. Second, each process requires vast quantities of water for cooling and other purposes. While much of the use could be consumptive, the quality of the water could also be degraded either thermally with the cooling process, or chemically by the huge scrubbers required for control of plant emissions. Third, but far from least, air quality would diminish. Assuming proper control were maintained at the plants, it would not likely decrease below existing Federal and State standards. However, pollution control technology has not reached the state where the present level of air quality could be preserved.

The recent Supreme Court ruling regarding nondegradation of existing air quality levels by industrial or other development may preclude the utilization of these processes in "clean" areas such as eastern Montana. In addition, if more than one plant were constructed, and if the wind were to combine their exhaust plumes, the cumulative effect could result in below-standard air quality and environmental damage even if the plants met the pollution control standards individually. Also, authorities do not agree as to the proper standard for some trace elements such as fluorine. At any rate, the equipment required for cleaning up the plant emissions could be fair-sized chemical plants in themselves.

TRANSPORTATION ALTERNATIVES

HIGH VOLTAGE TRANSMISSION LINES

Transport of energy in the form of electrical power from mine-mouth generation plants to the utility company marketing areas via extra high voltage (EHV) and ultra high voltage (UHV) transmission lines is a viable alternative to bulk shipment of coal. It is technically and economically feasible to transport energy in this form from the Ceded Area or Crow Reservation in Montana to the mid-western or northwestern sections of the country, as well as to other nearby marketing areas. This has been verified by the several huge power generation facilities now on line and others being constructed in the Four Corners area of the Southwest. Coal in the form of electrical energy is moving over a high-voltage transmission network from northwestern New Mexico to the Los Angeles and San Diego areas.

At present the economic cost of transporting coal in the form of high-voltage electrical energy is roughly comparable to shipping the coal in bulk form to market. Both methods of transport have their advantages and disadvantages, but, economically speaking, neither mode can circumvent the fact that distance to the market area and the product price structure are of prime consideration. Future cost of energy transport by this method may become even more attractive economically with a doubling in the growth of power loads every 10 to 12 years, increased efficiency in energy conversion, and the advent of large-scale inter-connection of local and regional power systems.(57)

Powerlines are a visual distraction and require about 23 acres per mile of right-of-way for each line. Foundation excavation would be required for the towers, and access roads would also be needed for construction and maintenance purposes.

UNIT TRAINS

Unit coal trains generally consist of 100 or more bulk loading gondola-type railroad cars, each of 100 tons or greater capacity, with adequate locomotive units to move the train efficiently over the route selected. The unit train was first used in 1960 by the Southern Railway Company for shipping coal from Southern Electric Generating Company coal mines to their power plants in Alabama.

Significant savings in transportation costs can be realized from regularly scheduled unit train shipment of bulk commodities. Some of the factors that contribute to cost savings are the type of gondola cars, optimum train size, motive power, train turnaround time and manpower requirements. The efficient scheduling, by-passing of regular terminals, lower turnaround time, and continuity of operation are probably the biggest contributors of savings in using unit trains instead of regular railroad operations. Keeping the train intact through loading, running, unloading, and returning is another area of significant transportation cost savings. Future concepts of unit train operations include fully automated systems requiring little or no on-train manpower.(58)

The major impacts occurring from utilization of unit trains would be: (1) the greatly increased traffic on the main railroad networks; (2) an increased incidence of accidents at grade crossings, derailments due to errors, etc; (3) the necessity for more frequent preventive maintenance; and (4) increased costs due to accelerated replacement schedules for rolling equipment and track.

COAL SLURRY PIPELINE

Coal slurry pipelines have been used to transport crushed coal over long distances in several previous coal mining developments. The most noteworthy is the 275-mile-long Peabody Coal Company Black Mesa pipeline in Arizona. A pipeline constructed underground would be environmentally desirable, since it is invisible except for pumping and storage facilities. The slurry pipeline has been proven to be an efficient coal transporting mechanism, and electrical energy requirements for transport of the slurry are minimal.

Some impacts of this alternative include the following: (1) The system does require water rights of around 700 acre-feet of water per million tons of coal for slurry preparation and pipeline transportation; (2) Treatment and disposal of the water, which is separated from the coal slurry at the downstream end of a pipeline, are associated problems; (3) Unless a power plant or other suitable market is available, recovery of the transport water is not feasible and it must be discharged to waste after treatment; (5) Provisions for transportation of mining equipment and supplies would still be necessary; (6) Rights-of-way (approximately

12 acres per mile) are required along the pipeline route; and (7) The possibility of pipeline spillage and rupture could degrade local areas.

SYNTHETIC NATURAL GAS PIPELINES

Natural gas is presently piped to market areas via large-diameter high-pressure pipelines. Synthetic gas from coal could be distributed in essentially the same manner and would provide a supplement to the nation's dwindling natural gas reserves. Extension of main trunk lines to SNG manufacturing areas would be relatively simple. Construction of a gasification plant and compressor station at mine-mouth installations would probably be the most economically feasible type of facility.

Adverse impacts from SNG pipelines and compressor facilities similar to those which now result from natural gas facilities would involve: (1) rights-of-way (amounting to about 12 acres per mile of right-of-way) along the pipeline route; and (2) the possibility of pipeline rupture, which could result in an extreme hazard to the environment.

RAILROAD SPUR LINES

Railroad spur lines could be utilized to ship coal from mining areas to existing railhead points and from there to marketing areas. Study of alternate rail spur routes would be required to allow for adequate consideration of economic, environmental, and social problems.

The route(s) selected should minimize the length of the spur line, adverse environmental impacts, and objections of property owners.(2)

Fewer adverse effects would probably result from extension of Burlington Northern rail spur lines that presently serve the Westmoreland Resources and Decker Coal Company mines. Proposed extension of these spur lines beyond the Peabody Coal Company permit area or the Shell Oil Company lease area into the interior of the coal reserve area should be studied in depth. The study is needed because of the more mountainous terrain on the Crow Indian coal reserve and the Gulf Oil Company permit area. Extension of a spur line eastward from the existing main line along the Little Bighorn River Valley might be more feasible.

Adverse impacts created by the construction of railroad spur lines would consist of: (1) the need for about 22 acres of land surface per mile of line for rights-of-way, (2) permanent disruption of the land surface due to cuts and fills, (3) possible retardance of flood flows along watercourses and the resultant hazard of a structure washout, (4) visual and noise degradation of the environment, (5) possible disruption of wildlife, and (6) accident hazards at grade crossings.

COAL CONVEYOR SYSTEM

Construction of coal conveyor systems would be considered a viable alternative to railroad spur line transport over distances as great as 15 miles.

Land requirements for a conveyor system would approximate or exceed those necessary for a railroad spur line. However, crossing of rights-of-way may be restricted by above-grade conveyor equipment.

The continuously operating mechanical equipment would have to be enclosed or completely isolated by fencing or other suitable means to eliminate a hazard to the environment.(2) Nearby residents would definitely be cognizant of the noise and dust problems associated with this equipment.

Electrical power would provide the necessary motive force, but a separate transportation system for movement of mining equipment and supplies would still be required.

TRUCK TRANSPORTATION

Truck transportation of coal from mine sites to a railhead on the Burlington-Northern main line would result in a much greater environmental impact than either of the two previous alternatives.

The land surface area required for paved heavy-duty highways would be several times greater than required for pipelines, conveyor systems, or railroad spur lines. The immense tonnage of coal to be moved would result in extremely heavy truck traffic which would be a hazard to pedestrian or automobile traffic. Motive power requirements created by such a fleet of trucks would far exceed (approximately nine-fold) that necessary for unit coal trains, and this increased fuel consumption would create an unnecessary drain on petroleum fuel reserves. Exhaust emissions to the atmosphere would also be increased several times. This alternative mode of mine-to-railhead coal transport would seem to be the least desirable.

ALTERNATE SUPPLIES OF COAL

Other coal sources could possibly supply the energy needs of the nation. Although the Crow coal resources are substantial and development of them is relatively desirable from an environmental viewpoint, billions of tons of other coals lie undeveloped. These huge reserves are located in various parts of the country and often are discussed in geographic terms.

WESTERN COAL

Expansion of existing centers of mining activity in eastern Montana is considered as a viable alternative. However, the confinement of strip mining activity to those areas already developed which are conducive to favorable mining conditions could have a lesser environmental impact, since virgin territory would not be involved. There is also merit in comprehensive large-scale development planning for a limited number of mining areas. Among the advantages are: (1) better utilization of existing service, transportation, and community facilities; and (2) confinement of possible pollution problems to fewer areas. However, in view of projected electrical energy consumption and enforcement of air pollution standards in heavily industrialized areas of the Midwest, the demand for low-sulfur western coal may outstrip the production and expansion capabilities of existing mining areas.

Some increase in adverse effects could be expected if mining were expanded in existing mining areas. Increased population and increased acreages of disturbed land, together with the associated impacts of these increases, will result. In addition, income would be lost to the Crow Indians if mining began or expanded in other areas as an alternative to mining on the Ceded Area or Crow Reservation.

The abundance of low-sulfur coal in eastern Montana and Wyoming prevents the Crow Reservation and Ceded Area from being unique in their ability to supply the needed coal. Indeed, a great many locations on Federal lands could be leased that contain low-sulfur coal. The environmental impacts of such an alternative would be similar to those covered by this report, although the degree of each impact might be greater or less depending on the location. A new site would merely transfer the possible physical environmental problems to another area. In addition,economic benefits to the Crow Tribe would not be realized, and existing social environmental problems would continue.

EASTERN COAL

Eastern coals are still available to supply a large share of the national energy needs. However, the high sulfur content of much of the strippable eastern coal makes it an undesirable source from an air pollution standpoint.

Lower sulfur coals in the East tend to be at greater depths and therefore require underground techniques. Underground mining of these coals would have the impacts described in the section on alternative coal mining methods.

ENERGY ALTERNATIVES

The following discussion of energy alternatives is presented to inform the reader of other energy sources presently available and those being developed for the future. These energy alternatives and/or the development of non-Indian coal reserves would serve as possible energy sources to offset losses in national energy production resulting from rejection of, or limitations in, implementation of the Ceded Area and Crow Indian Reservation coal leasing program.

Other than the supply implications of a "no action" decision on the coal leasing program alternative, the major adverse impact would be the direct effect on the Crow Tribe of Indians. The immediate impact would be to maintain already high levels of poverty, disease, welfare dependency, and unemployment because coal income would not be forthcoming to the Crow Indians.

The long-range impact would mean that development of the reservation economy would be limited to the level of tribal and Federal programs now in existence, and those proposed in the future. It also follows that the beneficial impact of a "no action" program would preclude the unavoidable, irreversible, and irretrievable environmental impacts of the Crow Indian coal leasing program described herein:

Information for the following discussion was condensed from several environmental statements, listed below, which may be referred to for additional detail and reference sources.

(1) Final E.I.S. for the Prototype Oil Shale Leasing Program Vol. II, 1973. Available from the U. S. Printing Office.

(2) Draft Environmental Statement of Development for Santa Ynez Unit, Santa Barbara Channel, California. Vol. III (pages VIII 81-265) DES 73-45.

(3) Draft Environmental Statement for Deepwater Ports. DES 73-37.

(4) Draft Environmental Statement of Proposed Federal Coal Leasing in the United States of America, 1973. (pages VIII 1-127) DES 74-53.

(5) Final Environmental Statement - Proposed Plan of Mining and Reclamation, Big Sky Mine, Peabody Coal Company, March 7, 1974. (Volume 1 of 2, pages 209-418) FES 74-12.

FUELS SUBSTITUTABILITY

The distribution of energy consumption in the United States for the four major sectors of the economy during the last decade can be broken down as follows:

Table 38 Distribution of Energy Consumption

	Coal	Natural Gas	Petroleum	Hydro & Nuclear	Total
Residential & Commercial	0.6%	10.7%	9.2%	--	20.5%
Industrial	8.1	15.3	7.4	--	30.7
Transportation	--	1.0	22.9	--	23.9
Electric Utilities	11.4	5.8	3.3	4.1	24.7
	20.1	32.8	42.8	4.1	99.8

Opportunities for substitution of one or more of these and other fuels or energy sources within the four sectors are probably greatest in the area of electric utilities and, to a lesser extent, residential and commercial use. The other two sectors of the economy are highly committed to natural gas (industrial use) as a clean fuel and petroleum (transportation use) to fuel the internal combustion engine. Substitution of the two major alternate fuels for electric generation would require 58,000,000 bbl of oil or 1,140,000 lbs. of U_3O_8 annually to equal the low level of coal development of 20,000,000 tons per year. At the high level 261,000,000 bbl of oil or 5,130,000 lbs. of U_3O_8 would be required.

Let us consider the more attractive opportunities available for fuels substitutability in the electric utility industry in more detail.

This sector of the economy uses about 25 percent of the energy consumed in this country, and projections indicate that by 1985, it will become the largest consumer.

Several factors must be considered in the substitution of different energy sources for electrical power generation, among which are cost, plant and equipment design, design and construction lead time, geographic location, fuel availability, and environmental considerations.

Cost of fuel substitutability has always been, and probably will continue to be, the main consideration in the changeover from one fuel to another. Transportation, fuel, plant equipment and other costs must all be thoroughly evaluated to determine economic feasibility.

In the immediate future, fuel substitutions in the power generating field can only be made among oil, gas, and coal. Nuclear plants cannot be utilized to burn fossil fuels, and geothermal installations are also highly specialized and limited to their prime energy source.

Acceptable lead time for design and construction of the short-term electrical power-generating capacity needed can be provided only by conventional or combined-cycle-type plants, for nuclear power plants require 10- to 12-year lead times. Many eastern power plants are equipped to burn both coal and oil, and the conversion from one fuel to the other is readily accomplished within several weeks. Conversion of existing coal-fired plants to oil or vice versa would require longer lead times of six months to a year.

Geographic location of power plants is related closely to the economics of transportation and fuels availability.

Environmental considerations are mainly in the areas of air and thermal pollution. Power plants have been the largest contributors to sulfur oxide pollution of the atmosphere. Substitution of low-sulfur fuels and installation of SO_x and fly-ash removal systems are presently being used by the electric utility industry to mitigate the atmospheric impact. Future power generation plant configurations being developed will greatly diminish the problem, while advances in cooling tower technology and use of new generating processes will eventually reduce thermal pollution and water consumption to a minimum.

The remaining three sectors of the economy are greatly influenced by the cost of substitutability, and by the cleanliness and controllability of the fuel. Natural gas and coal have fairly widespread use, but electricity has more applications in these areas. Petroleum products are the mainstay of the transportation industry and make up a good share of the residential and commercial heating fuel market.

Substitution of other energy forms for fossil fuels in the future is assured. The extent of this substitution will reflect the specific needs, supply and demand, technology, and controlling legislation.

By the year 2000 the probable trends in energy consumption in several of the energy use sectors may resemble the following:

(1) Coal will be a major source of energy in the power generation sector and a negligible source in the residential and transportation sectors.

(2) Natural gas will diminish in the electric utilities sector. Replacement with nuclear power is probable.

(3) Petroleum will still be dominant in the transportation sector.

Detailed speculation as to the extent of energy form substitutability by the year 2000 would not serve any useful purpose. Technological breakthroughs, stringent environmental legislation, and other factors could alter the situation as it is foreseen today.

COAL

The purpose of this description of the nation's coal resources and industry is to place in perspective the amount of coal considered for development on the Ceded Area and Crow Indian Reservation, as presented in this statement.

Reserves

The nation's coal reserves are more than adequate to support an accelerated schedule of energy development for many years. Coal is the nation's most abundant fossil fuel. It contains, on a Btu basis, about 89 percent of the identified energy resources available for use in this country.

Coal underlies 458,600 square miles in 37 states. The coal resources of ~~the nation~~ were estimated to total more than 3,200 billion short tons as of January 1, 1967, and nearly 1,400 billion tons are estimated to lie at depths less than 1,000 feet. Slightly more than 1,500 billion tons have been identified by mapping and exploration. Of this, about 200 billion short tons of all types of coal are commercially minable under present economic conditions and are considered as the recoverable reserve. The recoverable resource of low-sulfur coal to a depth of 1,000 feet in the nation is about 94 billion tons.

Coal resources in the Rocky Mountains and Great Plains were estimated to be 874 billion short tons as of January 1, 1967, including 188 billion tons in beds 10 feet or more thick and less than 1,000 feet below the surface. Approximately 47 billion tons of recoverable coal resources in the Rocky Mountains and Northern Great Plains can be extracted by surface mining. About 25 billion short tons of low-sulfur coal are considered the strippable reserve.

About one-half of the remaining coal resources in the West underlie the northern part of the Great Plains in very thick and closely-spaced beds of lignite and subbituminous coal. The coal generally has a low-ash-fusion temperature, a low sulfur content, a relatively low heating value, and a high content of volatile matter. The coal is usable for power generation, gasification, and liquefaction, particularly where strip-mined at low cost.

Utilization

Currently, coal provides about 20 percent of the total U. S. energy consumption, down markedly from earlier years when it provided most of the nation's energy (78 percent in 1920). Power generation accounted for 61 percent of the total U. S. coal production of about 610 million short tons in 1970. Coal for coke production consumed about 18 percent, and the balance, exceeding 100 million tons, was used for manufacturing, general commercial purposes, and space heating--markets that have been declining steadily in recent years.

Many technological, economic, and social factors will influence coal's future as an energy source. Among these are the timing and extent of increased nuclear power generation, volume of oil imports, and environmental restraints. More stringent health and safety regulations aimed at providing an acceptable working environment have decreased the number of underground mines, caused a loss in mine productivity, and required increased costs at underground mines. One result has been an increase in the number of surface mines and in the volume of production from them.

Northern Great Plains Resource Program

The department of the Interior announced on October 3, 1972, a Northern Great Plains Resource Program (NGPRP). The Northern Great Plains, which includes large parts of Montana, Wyoming, North Dakota, South Dakota, and Nebraska, has been the focus of increasing attention because the area contains vast amounts of relatively low-sulfur coal. The possibility of large-scale development of these coal resources has heightened concern over effective land use and resource planning, involving such issues as environmental quality, mined-area reclamation, competition for scarce water resources, development of other mineral resources, and potential effects on the population and economics of the Northern Great Plains States.

The local, state and Federal Governments which make land-use and resource-planning decisions affecting the Northern Great Plains area face competing economic, social, and environmental alternatives. The Federal Government makes decisions regarding leasing schedules for coal resources on public and Indian lands, regulations for air and water quality, and development of water projects. Congress is considering several measures related to strip mining. The states also are concerned with resource development; many have considered or taken legislative action related to strip mining and have prepared State Implementation Plans for air quality under the Clean Air Act. Local governments promulgate zoning and land-use plans, and provide for essential public services. Regional Commissions for economic development and water supplies share similar concerns and responsibilities. These overlapping local, state, regional and national interests are not well coordinated at this time.

These factors have led the five states, the Old West Regional Commission, and several Federal agencies to initiate cooperatively the NGPRP, in order to bring together and coordinate information that bears on the future development and environmental quality of the region. The outcome is intended to be a decision-making tool for Federal, state, and local interests who together must plan and manage the area's land and natural resources.

The environmental impacts of coal utilization are discussed elsewhere in this chapter. The reader is referred to the sections on Mining Alternatives, Coal Use Alternatives, Transportation Alternatives and Other Alternatives.

OIL AND NATURAL GAS

Crude Oil Imports

Importation of crude oil from foreign countries will continue to play an important role in supplementing the United States' demand for petroleum in the future. The most recent forecast of U. S. petroleum supply and demand in "U. S. Energy Through the Year 2000" by the Department of Interior is shown in the following tabulation:

Table 39

Total U.S. Petroleum Demand, Domestic Production and Supplemental Supplies Through the Year 2000 (million barrels per day)

	1971	1975	1980	1985	2000
Total Petroleum Demand	15.1	17.4	20.9	25.0	35.6
Total Domestic Production	11.3	11.0	11.8	11.6	10.6
Supplemental Supplies	3.8	6.4	9.1	13.4	25.0

This forecast does not reflect recent political developments on the international scene or the resultant state of flux in development of United States energy policy. The recent embargo on importation of crude oil from the Middle East to the United States necessitated stimulation of domestic crude oil production to supplement part of the national shortfall in crude oil supply. At present, the replacement of this embargo with an export quota system will result in continued stimulation of domestic production.

However, barring extreme stimulation of domestic oil production within the next five to ten years, much of the supplemental supplies needed will be met by importation of foreign oil. After 1980, an increasing portion of these supplemental oil supplies may be provided from other sources such as coal liquefaction, oil shale, tar sands, etc. It is anticipated that most of the imported oil would be supplied from the Middle East and North Africa where approximately 80 percent of the non-Communist world oil reserves are located.

At present the Mandatory Oil Import Program established in 1959 by Presidential Proclamation 3279 provides for the regulation of imported oil. The purpose of the Mandatory Oil Import Program is to protect the national security by restricting imports from foreign sources, thereby insuring a stable oil industry in the United States capable of exploring for and developing domestic reserves to replace those being depleted. Under the provisions of this program, oil import quotas could be increased sufficiently to provide the necessary supplemental supplies. On the other hand, oil import quotas could be replaced by a tariff system designed to limit oil imports, thereby stimulating domestic production. A combination of these two approaches could be utilized.

Modification of the Mandatory Oil Import Program in order to meet future oil demand is of particular concern because of the continuing political instability of the Middle East and North Africa supply sources. Increased balance of payment deficits and currency speculation are other concerns, since they are major factors contributing to monetary instability.

Direct environmental impacts of increased oil imports are related to the increased shipping traffic, to construction of on-shore or off-shore facilities for loading and unloading the more economical, very large crude oil carriers (VLCC'S), and to transporation of the oil from off-shore facilities to coastal refineries.

Increased shipping traffic would increase the incidence of oil pollution from (a) intentional discharges from ballast treatment facilities and tank cleaning operations; (b) accidental discharge during transfer operations; and (c) catastrophic events such as the breakup of the _Torrey Canyon_.

Since existing on-shore port facilities in the U. S. are unable to service tankers in excess of 65,000 DWT without extensive modification and related impacts, construction of off-shore terminal facilities is more desirable. These facilities would reduce shipping traffic and the incidence of collisions through the use of VLCC's. Dredging and oil spills in environmentally sensitive estuarine areas would be minimized or eliminated.

Transport of the oil from off-shore terminals to the refineries would be accomplished by pipelines. Environmental risks associated with these facilities are those usually encountered with pipeline construction and operation in off-shore environments.

Natural Gas Imports

Pipeline Imports - Both Canada and Mexico presently export natural gas to the United States. Since Mexico has only limited proven reserves and a recent policy of "self-sufficiency in energy," importation of their natural gas supplies is expected to cease after expiration of present contracts in 1982.

Future increases in natural gas exports from Canada may be limited due to recent actions by the Canadian National Energy Board (NEB). The NEB will allow exports only if their projected natural gas supply exceeds projected demand. Recent gas field discoveries in Canada may eventually result in larger reserves and a subsequent surplus.

Although the construction of pipelines may disrupt the environment during construction, the use of good construction practices and reclamation procedures suitable for the terrain and climate can mitigate most of the impact on the environment.

Liquefied Natural Gas (LNG) Imports - Importation of liquefied natural gas (LNG) utilizing large-scale ocean vessels is being planned by the natural gas industry. Feasibility of this method is afforded by the 600 to 1 volume reduction created by the liquefaction process. Long-term contracts for baseload shipments will be utilized to offset the decreasing reserves of domestic natural gas. The Federal Power Commission has recently approved two projects with combined delivery rates of more than one (1) billion cubic feet per day of LNG. These deliveries will require the construction of suitable terminal and transfer facilities for receiving the baseload shipments. Processing facilities for regasification of the LNG into the gaseous state will also be required.

Future levels of importation will be dependent on the success of the U. S. gas industry in obtaining long-term contracts and construction of facilities adequate to convey the LNG to processing and market areas. Proven natural gas reserves in the non-Communist world are adequate to assure export of surpluses to the United States. However, since a large part of these natural gas reserves is located in the Middle East and North Africa, the continuing political instability of this area may have a considerable impact on future importation of LNG.

The involvement of large LNG-carrying vessels in mishaps at sea or in port may not constitute an extreme hazard. Since natural gas is lighter than air, accidental releases of LNG (which remains liquid only when colder than -258° F at atmospheric pressure) would tend to dissipate rapidly through vaporization, polluting the atmosphere only until sufficient dispersion were attained. Little or no impact to the land or water would result. The hazard due to explosions is presently conjectural. LNG normally contains 80 to 90 percent methane, while an explosive mixture requires a methane concentration of 40 percent or less. Since the advent of commercial shipment of LNG in 1961, no serious fires or explosions have occurred.

During the transfer and storage of LNG to regasification facilities, considerable potential for explosion or fire exists, as past experience has shown.

Regasification facilities will require land for the plant site which will be permanently disrupted. Natural gas or water is used to regasify the LNG, and if water for a single-pass system is used, a nominal decrease in temperature will be experienced.

The benefits of lessened air pollution in the U. S. through use of a clean fuel such as natural gas cannot be overemphasized.

Oil Gasification

Gas can also be synthesized from petroleum. Gas has been produced commercially from petroleum in Europe, and some 40 plants are in the planning stage in the United States. Feedstocks to be used range from naphtha and other lighter hydrocarbons to crude oil. Oil gasification does not add to overall energy supplies, but it is one of the most promising short-term techniques of increasing the gas supply. Processes under consideration include:

(1) Thermal cracking in steam.

(2) Thermal cracking in a hydrogen-rich atmosphere.

(3) Catalytic cracking in steam.

(4) Partial oxidation.

Currently, much attention is being given to the Catalytic Rich (CRG) process developed by the British Gas Council. The CRG process can gasify a wide variety of hydrocarbon feedstocks, though attention now is concentrated on naphtha feedstocks. The CRG process includes desulfurization of feedstock, gasification, methanation, and purification to a gas having a heating value of 998 Btu per cubic foot.

Desulfurization of the feedstock is accomplished by mixing the feed with hydrogen-rich gas, vaporizing the mixture, and treating it with nickel molybdate and zinc oxide catalysts. If a high-sulfur feedstock is used, hydrodesulfurization is required.

The availability of light hydrocarbons and refining capacity to produce hydrocarbon feedstocks for SNG is questionable. About 20,000 to 25,000 barrels of hydrocarbon feedstock will be required to produce 100 million cubic feet of SNG.

Capital requirements for SNG plants using petroleum feedstocks will be about $800 million to $1 billion. Prices for announced projects are from $1.00 to $1.60 per thousand cubic feet.

The National Petroleum Council (1972) has estimated SNG production from petroleum feedstocks at 0.6 tcf (trillion cubic feet) in 1975 and 1.3 tcf in 1985. These figures are based on the assumptions that one-third of announced plants will be operating by 1975, and one-half of the plants scheduled to be in production in 1985 will be completed on schedule.

The environmental impacts from operation of oil gasification plants using petroleum-base feedstocks are expected to be similar in many respects to those of comparable coal-based gas synthesis plants. However, these plants would not discharge comparable levels of ash, char, sulfur oxides, or particulates. In the case of plants using naptha feedstock, none of these latter contaminants would be discharged.

Increased Outer Continental Shelf Production

This alternative would require the increased exploration, development and production of crude oil and natural gas from offshore areas. Supplies equal in energy to a portion or all of that lost by a reduction or elimination of Crow Indian coal production would have to be located, developed and produced. These supplies would be in addition to those already projected for production.

Accelerated leasing in offshore areas was scheduled after the President's Clean Energy message on June 4, 1971. Scheduling of sales doubling the previous rate, including both traditional and virgin leasing areas, was proposed. Leasing in frontier areas (depths greater than 200 meters) has also been proposed. However, present development of petroleum resources in offshore areas has not progressed sufficiently to meet projected requirements. This dilemma is the direct result of a court injunction following the first sale.

Stimulation of additional development might require price increases, subsidies, tax benefits , and changes in leasing procedures. The quantity and delivery schedule of resultant increased supplies are unknown but might be restricted by availability of exploration and development equipment.

Offshore leasing and subsequent development and production results in a variety of impacts on the natural environment, other resources, air and water quality, land use patterns, and the economy. Most of these impacts are caused by offshore construction, various related operations and accidental mishaps, all resulting in release of debris or pollutants to the environment. Areas affected by adverse impacts are described in the following paragraphs.

Biota of the ocean - Environmental impact on the oceanic ecosystem results from facilities construction, pipeline burial, debris, dicharge of drill cuttings and drilling fluids, and the accidental release of oil and other toxic materials. The environmental effects are felt by both pelagic and benthic marine life.

Biota of the beach - Major factors affecting this ecosystem are oil spillage contamination and disruption due to pipeline construction. Impact on the littoral zone due to oil spillage is quite pronounced, usually resulting in death to oiled plants and animals.

Biota of embayments, channels, and water courses - Oil spillage and dredging operations constitute the main factors which could affect this ecosystem adversely. This is a particularly critical ecosystem since it is a rearing ground for the young of many biological species.

Biota of the marshes - Adverse impacts to this ecosystem would occur in the form of oil spillage, pipeline construction and siting of pipeline transfer and regasification facilities.

Air quality - Adverse effect on air quality would be limited to emissions from surface vessel and stationary power plants and from accidental releases of oil and gas caused by wild wells. A burning oil well would have a much greater impact on air quality than a gas well, because of byproducts from incomplete combustion.

Water quality - Degradation of water quality would result mainly from debris and bilge water from surface vessels; from discharge of drilling fluids and cuttings; from production and discharge of highly saline formation waters; and from accidental oil spillage.

Commercial fisheries: Underwater obstructions, offshore structures, debris, and oil spillage are the main factors related to offshore oil and gas production which affect the fishing industry.

Navigation and ship traffic Offshore structures and service vessels are most often involved in collisions with major shipping traffic.

Recreation, sport fishing and esthetics - Construction and accidental oil spillage would adversely affect these categories temporarily. Presence of offshore structures enhances sport fishing by providing favorable fish habitat.

Land use - Onshore land use for pipeline facilities would create temporary loss of land during construction.

Gas well blowouts - Release of hydrocarbons during a blowout can produce a serious potential for offshore water pollution. The seriousness of the problem depends upon the amount of petroleum fluid produced from individual gas wells.

Increased Onshore Production

Increased exploration, development and production of crude oil and natural gas would be necessary to make this a viable alternative.

Supplies of energy equal to all or a significant part of projected supplies from coal production on Crow Indian leases would have to be developed in addition to the supplies projected for production from onshore sources. Past performance of the industry in developing onshore crude oil and natural gas supplies indicates that it would have trouble providing additional supplies to satify greater demand at a time when increasing supplies are also required to offset continuing declines in oil field productivity.

The continuing decline in onshore drilling in recent years has been the result of minimal economic incentive. With additional incentives such as subsidies, price increases and tax benefits, an increase in exploration, development and production of domestic supplies could be anticipated. However, the crude oil production necessary to offset a maximum annual coal production of 66 million short tons of 9,000-Btu/lb coal from the Crow Reservation by the year 2000 would exceed a half-million bbl/day production rate.

Recent calculations of the Geological Survey indicate the following proven reserves and recoverable resources for onshore oil and gas production:

Table 40 U.S. Onshore Oil and Gas Reserves and Resources

	Proved Reserves		Recoverable Resources 1/	
	Oil 2/	Gas 3/	Oil	Gas
Public Lands	3.0	14.0	250.0	1,153.0
Non-public Lands	38.3	237.6	16.0	61.0
Total	41.3	251.6	266.0	1,214.0

The oil and gas resource figures above include those for the Alaska North Slope. Eventually this region may be classified as one of the richest in the nation if future exploration indicates a favorable potential.

Secondary recovery techniques currently employed have extended the productive life of many oil fields. Present recovery levels of original oil in place range from 13.5 percent to 65 percent with an average of about 31 percent. However, significant increases in future crude oil production through secondary recovery procedures probably will come only with future technological advances. At present

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1/ Not including proved reserves

2/ Oil in billions of barrels

3/ Gas in trillions of cubic feet

secondary recovery operations on existing and new wells are necessary to maintain present production rates in many fields, precluding any increase in production.

Air quality - The main impact on air quality would come from the emission of particulates and gaseous material into the atmosphere. Temporary quality reduction from loss of ground cover, vehicular traffic, equipment failure, and well blowouts would be short-term in nature. Production and storage facilities would create longer-term degradation on air quality. However, it is unlikely that permanent changes would be effected after cessation of operations.

Land quality - The modification of land forms necessary for petroleum production results in varying degrees of environmental impacts on the physical and chemical land characteristics, biological conditions, and ecological relationships.

Construction of roadways would progress from limited access during exploration to a more extensive network during development and production. Subsequent disturbance of the vegetation, drainage and topsoil could result in erosive drainage and changes to land forms, increased siltation of streams, and alteration of wildlife habitat.

Land use and recreational activities would also be disrupted during drilling, production, and transportation operations.

Construction of pipeline facilities has the potential for causing unfavorable environmental impacts in many areas, particularly in a fragile environment such as along the proposed trans-Alaska pipeline.

The reader is referred to the Department of Interior Final Environmental Impact Statement - Proposed Trans-Alaska Pipeline, of March 1972, for detailed evaluation of these environmental impacts.

Land pollution from salt water and accidental oil spills would occur mainly during drillings, production and transport operations. However, most ground spills cause little ground pollution. The principal cause of accidental ground spills is from corrosion of the older cathodically unprotected pipelines.

Water quality - Water quality of surface and groundwater supplies is affected by land erosion caused by construction activities, and by accidental release of oil, chemicals, saline formation waters, and waste materials to receiving streams and aquifers.

Increased turbidity in streams and accelerated siltation of reservoirs and estuaries can have an adverse impact on flora and fauna, recreation activities, and esthetics.

Probably one of the major environmental impacts is caused by accidental or improper disposal of produced saline formation waters. Contamination of potable surface and groundwater supplies can have long-term environmental effects on flora and fauna and on groundwater quality.

Deregulation Of The Wellhead Price Of Natural Gas

The sale of natural gas for resale in interstate commerce is currently under Federal Power Commission (FPC) jurisdiction. In 1954, the Supreme Court ruled that independent producers of natural gas who sell for interstate commerce were not exempted from regulations under the Natural Gas Act.

Although in the past few years, the FPC has modified its pricing policies to be more responsive to the gas supply situation, the FPC Chairman, on April 10, 1973, urged Congressional action to amend the Natural Gas Act to decontrol the price of new gas supplies. The President, in his energy message to Congress on April 18, 1973, also proposed such action. Concurrent with the President's Energy Message, the Department of the Interior submitted to Congress proposed legislation to amend the Natural Gas Act. Until such legislation is passed by Congress, however, the wellhead price of new gas will continue to be regulated by the Federal Power Commission.

Deregulation of the price of new gas is a policy option that, if implemented, should stimulate the economic incentive for the discovery of new supplies and reduce inefficient use of the fuel. To determine the effectiveness of such policy options on these objectives, estimates of the producers' and consumers' responses to increasing prices are needed.

When prices rise, producers have a greater opportunity for profit in developing resources which otherwise might seem too risky or uneconomical to develop. On the other hand, consumers are less willing to pay higher prices and may curtail some of their uses of the fuel, tending to bring supply and demand into balance. While supply and demand elasticities have been the subject of much research, very little is known of the quantitative relationships.

Six econometric studies on price demand elasticity were reviewed by Professor Draper in "Regulation of the Natural Gas Producing Industry."

These six studies show widespread differences in the demand elasticity of natural gas. Each study has its problems and limitations, as pointed out by Draper, making reliance on any particular set of elasticities suspect.

Demand elasticity is analyzed in the six studies in terms of end users only. However, it should be pointed out that supply and demand elasticities at the wellhead are more pertinent problems. None of the study reports discuss these problems although wellhead demand is derived from user demand.

In summary, little can be said with assurance except that demand elasticity is negative. If the wellhead price of gas is deregulated, however, and the price increases ten percent, any decrease in demand by pipeline companies in the short-run might be expected to be less than ten percent.

Four recent studies have been made concerning price-supply elasticity. Although questions have been raised concerning the accuracy of these studies, the results have not been as divergent as those in studies of demand elasticity.

It appears that a supply elasticity of 0.5 might be a reasonable consensus of supply response to price. If the average wellhead price is 20¢ per Mcf (thousand cubic feet) and the yearly production is 25 tcf, an increase in price to 40¢ might raise the available production from 25 tcf to 37.5 tcf. This amount would be lowered by the counterbalancing effect of the elasticity. It is difficult to determine the demand elasticity, because demand has been established in reference to consumer prices but not to wellhead prices, and because the values of those elasticities vary greatly.

A thorough analysis of the environmental impact of degradation of the wellhead price of gas is currently in process at the Department of the Interior. In the interim, it should be noted that this alternative would not result directly in any specific action. It would, however, trigger market forces which would result in increased activities affecting the environment. These activities would center on increased domestic production of recoverable natural gas and associated oil, both onshore and offshore.

Nuclear Stimulation Of Natural Gas Reservoirs

Utilization of nuclear explosions to increase natural gas production from low-yield and known reservoirs has been effectively demonstrated by Projects Gasbuggy and Rulison. The method has the potential to materially increase the nation's recoverable natural gas reserves. Over 10 percent of the nation's current natural gas requirements could be met by a moderate development program. However, the safety technology needed to permit use of nuclear explosions in this way has not been developed at present. Currently the U. S. Atomic Energy Commission's Plowshore Program is developing such technology.

Environmental considerations other than those common to natural gas development, include residual levels of radioactivity in the natural gas product and the ground motion caused by the explosion. The detailed environmental impacts of this nuclear stimulation program are described in AEC's environmental statements for the above projects in Rio Blanco County, Colorado, and Sublette County, Wyoming.

Oil-Shale

Oil-shale deposits underlie large areas of the United States, with those having the greatest potential located in Colorado, Utah, and Wyoming. Public lands comprising some 73 percent of oil-shale lands contain nearly 80 percent of the shale oil. Approximately 600 billion barrels of oil are contained in high-grade deposits over an area of 17,000 square miles.

At present three separate retorting processes have been developed to the point where they are technologically feasible, but commercial production has not been accomplished. Mining methods utilized would be conventional underground room and pillar, or surface stripping and/or open-pit mining.

In accordance with the President's Energy Message of June 4, 1971, the Secretary of the Interior announced plans for a proposed prototype oil-shale leasing program on June 29, 1971. The draft environmental statement for this program was released by the Department in September 1972. That statement details the proposed program and assesses the specific impacts anticipated from prototype development and development on private lands that may be stimulated by the Department's action, should the program be implemented.

After the establishment of the proposed prototype program, the timing of commerical production will depend on the industry. Therefore, determination of the exact quantity of oil that may be extracted is not possible. However, the departmental statement does present the probable maximum rate of development that might occur for planning purposes. This potential is shown below:

Table 41 Potential Shale-Oil Production

Year	Maximum Estimated Shale-Oil Production in Million Barrels per Year
1975	18
1980	100
1985	365

After 1980, second generation extraction retorting systems would allow substantial increases in the annual shale-oil production. However, significant quantities of oil from oil-shale will probably not be available before 1980, due to economic, technical and environmental factors.

Development of oil-shale deposits would cause direct and indirect environmental changes in the three-state region where commercial oil-shale deposits exist. Environmental changes of both local and regional significance would occur, causing conflicts related to other physical resources and the use of land and water. Impacts would occur to the land, water and air quality, flora and fauna, agriculture, recreation, esthetics, and social and economic patterns. The following discussion of impacts has been summarized from the Department's draft environmental statement.

Land quality - Commercial development of an oil-shale industry would require roads, mining, processing plant sites, waste disposal areas, utility and pipeline rights-of-way and associated services during the productive life of a lease. Land use patterns would be changed until restoration to original or improved conditions occurred upon completion of mining. Waste disposal in canyons and arroyos in conjunction with contouring and revegetation could reduce erosion and restore the area esthetically. Subsequent land use would depend upon the particular revegetation program selected. Significant impact may occur locally, but on a regional basis only a slight effect is anticipated.

Water quality - Sufficiently dependable water supplies would have to be obtained from the Colorado River or its tributaries, requiring the construction of dams and reservoirs or purchase from existing reservoirs. Water supply problems could occur due to overappropriation of Colorado River water. Storage, diversion and consumption of water resources would further aggravate water quantity and quality problems. Increased sediment contributions will occur due to erosion of mined lands prior to revegetation. Population influx will also create increased demands on the quantity and quality of surface and groundwater supplies. Disruption of groundwater resources due to mining operations would cause an adverse impact.

Air quality - Adequate techniques and advanced technology already exist for adequate control of some gaseous and most particulate emissions from mining and processing plants. It is anticipated that applicable Federal and state air quality standards would be adhered to.

Flora and fauna - Construction and operation of mining and processing facilities would have varying degrees of impact on the flora and fauna. Loss of habitat and associated food, cover and water resources would result from development. Accidental or uncontrolled release of pollutants to surface and groundwater supplies could have considerable adverse effect on aquatic habitats outside the developed areas. Oil spillage from handling, storage or transmission facilities would have a deleterious effect on the land-based flora and fauna. Urbanization would also create stress on regional wildlife populations.

HYDROELECTRIC

Conventional hydroelectric developments are dependent upon the magnitude of stream flow, as related to reservoir storage, and the height of fall created by a dam to produce electric power.

The U. S. has a potential hydroelectric capacity of 179,900 MW, of which 51,900 MW or 28.8 percent has been developed. Of the remaining undeveloped capacity of approximately 128,000 MW some 32,600 MW is in Alaska; 65,000 MW is located in the Mountain and Pacific regions; and 30,400 MW of capacity potential could be developed elsewhere in the United States.

Federal Power Commission projected levels of electric generating capacity in the U. S. are shown below:

Table 42 Projected Levels of Electric Generating Capacity

Year	Total Generating Capacity (MW)	Total Hydroelectric Capacity (MW)	Hydroelectric Percentage
1970	340,058	51,641	15.2
1980	665,000	68,000	10.2
1990	1,260,000	82,000	6.5

Pumped storage projects also generate hydroelectric power. However, they are utilized to generate high-value peak energy during high-demand periods. These projects consume more energy than they produce by using low-cost off-peak energy to refill storage pools.

Most dams constructed today are for multipurpose uses which are frequently dominant over hydroelectric power generation.

Substitution of hydroelectric power for coal used by electrical utilities is a viable alternative in some areas of the country. However, many of the more favorable sites have already been developed leaving those less attractive economically.

The Bureau of Reclamation and Corps of Engineers have filed numerous environmental impact statements for specific hydroelectric projects, and the reader is referred to them for more detail.

Hydroelectric power produces no air, heat or water pollution, except for increased dissolved-solids concentrations from evaporation and diminished oxygen levels in stored water. Impact on the land and water resources is generally confined to the dam site and reservoir vicinity.

Construction of a dam and reservoir irretrievably commits the affected land area to water storage. Reservoir sedimentation caused by detention of streamflow progressively reduces reservoir capacity. However, the reduced sediment bedload will significantly diminish erosion downstream.

Fish and wildlife may be adversely affected unless adequate design provisions for their safety are included in such projects.

NUCLEAR

Within the next 15 years commercial use of nuclear power for electrical generation is expected to increase considerably. Installed capacity (as of 1970) of 12,000 MW is projected to increase along the lines shown in Table 43, depending on licensing delays.

Table 43 Projected Capacity of Nuclear Power

Year	Installed Nuclear generating capacity in MW Minimum	Powered Electrical Capacity in MW Maximum
1975	46,000	61,000
1980	120,000	139,000
1985	198,000	286,000

Most nuclear power generating plants currently operating are of the light-water thermal reactor type. The heat energy from nuclear fission is transferred to circulating water in the fuel core and is then used to generate steam for turbine generators. Several high-temperature gas-cooled reactors have also been completed or ordered. These reactors have a low fuel utilization since they can convert less than two percent of the energy available in uranium to electrical power. Today development is being concentrated on breeder-type reactors which may be capable of utilizing up to 60 percent of the total energy from uranium, and thermonuclear fusion-type reactors are not expected to be a commercial reality before the year 2000. Additional nuclear plants could not be expected to provide a substitute source of energy before 1980 because of the six or eight year lead time required by the industry.

Substitution of nuclear power for coal used in electrical power generation would be a viable alternative mainly in the Upper Midwest and Northeastern States where adequate water supplies are located.

Environmental effects from nuclear power generation are associated with surface and subsurface mining of uranium ore, changes in land use, disposal of waste heat, the risk of serious accident, and the safe storage of highly radioactive wastes.

Land Quality - Mining of uranium is concentrated in isolated semi-desert areas of the western states. The uranium ore is mined by open pit or underground methods depending upon the geologic conditions. Because of the low concentration of U_3O_8 in uranium ore, a considerable amount of surface area is disturbed by open pit mining methods. Also, milling of the low-concentration uranium ore produces considerable amount of low-level radioactive tailings that require containment from the environment. Disposal of these tailings as backfill in the open pits and mined-out slopes of underground mines has been proposed for the future.

One particular hazard of the underground mines are the gaseous, radioactive products. A high incidence of lung cancer in miners who were overexposed during the 1950's has been reported. Lower annual exposure limits are expected to reduce the high incidence greatly.

Nuclear power plants would require about 500 acres of land per site for 3,000 MW of generating capacity. If cooling ponds are necessary, an additional 3,000 to 6,000 acres could be required. Plant construction would cause temporary environmental problems, and electrical transmission lines would require 10 to 15 acres per mile of line.

Air quality - Gaseous emissions of small amounts of radioactive material are carefully controlled at nuclear power plants. Release of radioactivity is limited to less than one percent of the individual maximums allowed. This is only one-fourth to one-third of natural radiation exposure.

Water quality - Due to the lower thermal efficiency of nuclear power plants (33 percent vs. 40 percent for new fossil-fueled plants), a light-water reactor will release approximately 50 percent more waste heat than a fossil-fuel plant of similar size. Elimination of the waste heat can be accomplished by various methods, such as evaporation from cooling ponds and wet cooling towers or use of single- and double-pass flow-through systems. The flow-through systems would transfer the waste heat directly into the lake or river utilized as the source of cooling water. The effects of the waste heat would depend on the size of the water source. Flora and fauna of smaller lakes and rivers could be affected significantly.

Discharge of radionuclides in the cooling water would be very small, on the order of less than one percent of the individual maximums allowed.

Plant accidents - The design of nuclear power plants utilizes the "defense-in-depth" principle to minimize the adverse effects of accidents. Siting, prevention and containment of accidents are all considered in the design. The maximum radiation dose which could occur at the plant site boundary would not exceed the annual dose due to natural radioactivity.

Transportation - Transportation of spent nuclear fuel elements from reactors to processing plants and high-level wastes from reprocessing plants to storage sites poses a considerable hazard. Transportation regulations and containers have been developed to assure no release of radioactivity to the environment.

Fuel reprocessing - Spent nuclear fuel elements are reprocessed for recovery of usable nuclear fuel and separation of radioactive wastes. Although radioactive emissions during reprocessing are higher than occur at nuclear power plants, the estimated dose received by the affected population is still two orders of magnitude below natural levels.

Radioactive-waste storage - Because of the high concentration of radioactive nuclides and slow decay rates, isolation of the waste materials for hundreds of thousands of years is required. Presently man-made storage facilities are utilized, although natural depositories are being considered.

GEOTHERMAL POWER

Geothermal energy in the form of natural heat energy from the earth's interior is presently utilized for power generation by Pacific

Gas and Electric Company at their Geysers, California, operation. Currently 192 MW of capacity has been developed with a potential for up to 2,000 MW.

Exploration efforts are continuing in California in the Imperial Valley, Morro Lake and Modoc County. Other sites at Chandler, Arizona, and Valle Grande, New Mexico, are being investigated. Areas in Oregon, Washington, Idaho, and Montana are also classified as geothermal resource areas. Exploration is being conducted on private and public land.

Development of geothermal energy is similar to oil and gas industry operations, except that water under pressure in the gaseous and fluid state is produced. Conversion of the steam to electrical energy presently utilizes low-pressure steam-turbine systems.

Geothermal energy is a feasible means of supplementing or supplying power on a local scale, but cannot serve as a substitute for other large-scale forms of power generation. It is estimated that geothermal energy will comprise less than one percent of the nation's power generating capacity through the year 2000.

Land - Environmental problems from exploration and development of geothermal resource areas would be similar to those experienced in the oil and gas industry. Construction activities such as drilling, road building, pipeline installation, etc. would constitute similar cause-and-effect problems. Production and transmission facilities would be similar to conventional steam generating plants.

Air quality - Release of gaseous wastes produced by the hot water or steam could constitute an adverse impact unless their removal and disposal from plant effluents is practiced. Well blowouts during drilling operations could also introduce gaseous contaminants into the atmosphere.

Water - Geothermal reservoirs may be classified as yielding either vapor (high steam-low water yields) or hot water (which at elevated temperatures flashes to steam). Most if not all of the geothermal areas in the United States yield hot water.

Well blowouts during drilling operations could release hot fluids and other contaminants to the environment, with the possibility of surface and ground water pollution. Proper precautions in design, construction and operation of geothermal systems can minimize this hazard.

Groundwater aquifers may be intimately associated with geothermal reservoirs which contain hot saline water. The construction of wells tapping geothermal reservoirs must provide adequate protection of those aquifers containing potable water in order to prevent irreversible impacts.

Seismicity - Seismic stimulation of an area of geothermal activity may be caused by marked changes in reservoir pressure from fluid production or injection. This is particularly evident in areas of geologic faulting and fracturing. The occurrence of this phenomenon in several areas of the United States is well documented. Although major earthquake activity has not resulted, the potential exists.

Subsidence - Withdrawal of large volumes of fluid from an operational geothermal reservoir may result in local subsidence of the land surface. Reinjection of the reservoir fluids is required to maintain stability of the system in many instances.

Waste disposal - Discharge of most geothermal waste fluids into streams or lakes would not be an acceptable disposal method due to excessive minerals concentrations. Although discharge to the oceans might be acceptable chemically, the excessive temperature of the waste water may prevent it. At most sites reinjection into the geothermal reservoir would be an acceptable solution to problems of waste water disposal as well as maintenance of pressure in the system.

Other environmental problems such as noise from steam injection or expansion, fogging from use of cooling towers, and the need for electrical transmission lines must also be considered.

TAR SANDS

Shallow-depth deposits of viscous hydrocarbons impregnating bedrock which cannot be recovered by conventional means are termed tar sands. Production of hydrocarbons from these deposits requires the addition of energy to the system. Several commercially desirable foreign deposits are located in the western hemisphere, chiefly at the Athabasca deposits in northern Alberta, Canada, and the Orinoco deposits in eastern Venezuela.

In the United States, the only deposits having commercial promise are in the State of Utah. Recoverable reserves from the Utah deposits are estimated to be 10 to 16 billion barrels of oil. These deposits are not susceptible to mining and would require development of in situ recovery methods. An adequate water supply for development is lacking. Since these deposits are mainly on Federal lands, leasing cannot be allowed until legislation is passed.

Land - Exploration for and mining of the tar sands would require construction of access and permanent road systems and commitment of land to the mine, whether from mining extractions or in situ methods. On-site processing facilities and development of housing would further increase the land area affected.

Water - Exploration and mining procedures could cause contamination of groundwater aquifers. Consumptive use of groundwater for mining, processing and housing facilities would constitute an irretrievable commitment of this resource, and water-borne wastes from these uses would require contaminant treatment. Transportation of refined petroleum products would provide the possibility of accidental spillage and related environmental problems.

Air - Dust and refinery noxious gas contamination would constitute the major threat to air quality.

OTHER ENERGY SOURCES

Biological Energy

Biological energy may be derived from (a) the conversion of surplus cereal grains through fermentation into ethyl alcohol fuel, (b) the collection and conversion of organic wastes into usable oil, (c) the growing of timber and other crops for fuel energy and (d) the conversion of animal by-products into fuels. Items (a) and (b) would seem to be the most feasible, although the associated collection and processing costs, inadequate technology, and high capital costs make these energy sources economically unattractive at present.

Environmentally, the use of surplus crops and organic wastes for fuel could possibly reduce some associated adverse impacts which presently occur. However, the world food shortage may demand export of the food surpluses.

Solar Energy

Solar energy is a source of both heat and electro-magnetic radiation with both direct and indirect use possibilities. An indirect use would be burning of wood and other combustible plants. Direct use would require conversion by solar cells to a usable form of energy. Fossil fuels represent stored solar energy which was converted to a usable form in past ages.

The land surface area of the U. S. intercepts about 600 times the nation's total 1974 energy requirements at a radiation intensity of one kilowatt per square meter or less. Assuming the efficiency of 10 percent, each square meter would produce up to 100 watts of peak power. Heat energy so generated could have numerous applications. However, the low energy-collection efficiencies of solar cells, combined with energy storage requirements due to the intermittent source, result in prohibitive development costs. Major technological improvements in the conversion of solar energy to a usable form will be required before the solar energy source can be economically utilized on a large scale. Assuming use of this energy form with the present state of technology, some desert areas of the U. S. could become vast energy collection farms and might thereby experience major esthetic and environmental impacts.

Tidal Energy

Tidal energy is a hydroelectric power source which is derived from the alternate filling emptying of a bay or estuary that can be enclosed by a dam. Passamaquoddy Bay, Maine, and Turnagain Bay in Cook Inlet, Alaska, are the only areas in the United States that might be economically feasible. The Canadian government may develop a portion of the Bay of Fundy by 1985. The impact of this energy source would be minimal in view of the energy requirements of the U. S., and does not represent a significant alternative. Environmental considerations associated with damming a bay or estuary would be significant.

Wind Energy

Wind energy is the result of atmosphere circulation at the earth's surface caused mainly by alternate solar heating and cooling, storage and release of heat energy from the oceans and land surface, and rotation of the earth. The capture and use of this energy requires a machine capable of converting linear kinetic energy into a rotational form about an axis for conversion to electric power. Economical power generation requires an average wind velocity of about 30 mph of a nearly constant magnitude and direction, and topography in which boundary layer effects are minimal. Presently, the high cost of initial equipment installation, energy storage and standby energy facilities, and the intermittent nature of wind energy, precludes development of this source. Even though the source is pollution-free, it does not appear to be a viable alternative to large-scale energy sources.

Fuel Cells

A fuel cell is an electrochemical device in which the chemical energy of gaseous or liquid fuels is converted directly into low-voltage direct-current electricity. The fuel cell can attain an efficiency of 50 to 60 percent or more. Almost one and one-half times the amount of electricity can be generated from a ton of coal in a fuel cell as in a conventional power system. However, the unproven economic feasibility of this method plus the lack of performance on a large scale prevents its being considered as a viable alternative.

Hydrogen

Hydrogen gas can be used as an alternative to fossil fuels. The gas can be manufactured by subjecting water to the process of electrolysis, thereby separating the hydrogen and oxygen components into their gaseous forms. However, hydrogen presently used by industry is obtained mainly through the refining of natural gas and oil. Cost-wise, hydrogen is about 50 percent more expensive than gasoline on a Bty-per-unit-weight basis. Transmission costs for this gas would also be higher, due to the lighter weight in the gaseous state. The main attraction of hydrogen as a fuel is in the residential-commercial and transportation sectors of the economy. The internal combustion engine can utilize hydrogen fuel, although at a lower efficiency, and at the same time meet or exceed 1975-76 Federal emission standards. Water is the major byproduct from combustion of hydrogen.

Thermoelectric

When two dissimilar metals are joined in a loop and one of the junctions is heated, an electric current flows in the loop. This thermoelectric phenomenon will receive continued attention for special low-power application such as for control devices. Short operating lifetime, high temperatures, and undesirable heat transfer from the hot to cold will be major obstacles to producing large quantities of electricity.

Thermionic Generation

When a metal is heated sufficiently its electrons acquire enough energy to overcome retarding forces at the surface of the metal and escape or "boil off." If the electrons are collected on another, cooler metal surface, electrical energy can be generated by joining the two pieces of metal with an external circuit. Thermionic generators, as these devices are called, are a type of heat engine, and their efficiency theoretically is limited to 35 to 40 percent. Thermionic development during the next decade will be concentrated in aerospace activities, and large-scale industrial thermionic generation is not likely within the next several decades. Hence, such conversion systems do not represent an alternative energy source to coal in the near future.

OTHER ALTERNATIVES INVOLVED IN PROCESSING

Sulfur Dioxide Removal

Continuing utilization of high-sulfur-content eastern and midwestern coal at existing power-generating plants could be accomplish by removal of the sulfur content from the raw coal, injection of low-cost chemical additives into flue gas streams to convert sulfur dioxide into physically trappable compounds, and installation of chemical processing equipment to facilitate the removal of sulfur dioxide from flue gases.

The technology for removal of all sulfur from coal is presently unavailable. However, research on mechanical removal of the iron pyrite mineral content in coal pulverization processes at power generation plants is being developed. Removal rates of over 70 percent of the pyrite are possible. However, in many coals the organic sulfur, which comprises from 50 to 70 percent of the sulfur content, is not removable by mechanical methods.

The recovery of sulfur oxides after combustion by use of chemical additives is technologically feasible. The use of a low-cost additive chemical which will react with the sulfur oxides by converting the gas to a solid, in conjunction with fly-ash removal devices, is extremely attractive due to the relative simplicity and low capital cost. The most promising additives are pulverized limestone and dolomite. Under proper operating conditions the use of these additives can effect a removal of up to 30 or 40 percent of the sulfur dioxide content of flue gases, though the removal rate is highly dependent upon the particular reactive character of these naturally occurring carbonates. A modification of this process is the use of a wet scrubber to collect the solid material produced. With this type of system, removal of as much as 70 to 80 percent of the sulfur dioxide may be effected, although a 50 percent removal level is probably more realistic under high to maximum operational loadings of power plants. The by-product of this process is calcium or magnesium sulfate which has little or no commercial value and must be disposed of.

Several Japanese processes offer methods of SO_2 removal that have many advantages. One of these processes contacts the flue gas with dilute sulfuric acid in an absorber, where the absorbed SO_2 is oxidized to SO_3, which forms H_2SO_4 (sulfuric acid) in the water. The resultant acid is contacted with limestone outside the absorption cycle to form calcium sulfate. An advantage of this system is that no slurry is circulated in the absorption facilities.

The sulfur removal would result in transportation cost savings because the eastern and midwestern coals are 500 to 800 miles closer to the points of consumption than the coal from the proposed mining site. The higher Btu content of eastern coals would result in further transportation savings.

Under development are chemical sulfur dioxide removal methods that require sophisticated equipment. These are the catalytic-gas-phase process and the alkalized-alumina process. These processes may be utilized in the dry phase or wet scrubbing equipment may be added to convert the processes into a wet phase. The sulfur dioxide content of stack gas emissions may be reduced from 80 to 90 percent, and recovery of salable sulfur compounds is an added benefit.

Modify EPA Requirements

The modification of the Environmental Protection Agency's restrictions on SO_2 emissions from the utility plants could permit the continued use of eastern and midwestern coals and thereby reduce the demand for low-sulfur western coals. Such modifications would slow the economic growth of the Northern Great Plains Region. High SO_2 emissions would remain and contribute to the air pollution problem in the midwest manufacturing area.

COMBINATIONS OF ENERGY ALTERNATIVES

In the interest of clarity, this statement includes a separate discussion of each potential alternative form of energy as a possible substitute to the leasing and mining of coal from the Ceded Area and Crow Indian Reservation. The Crow Indian coal will play an important role in the energy spectrum of the northern Midwest, an area already in short supply of oil and gas. If the leasing and mining of Indian-owned coal in the Crow Indian coal resource area is prevented, an equivalent amount of fuel energy will have to be supplied from another source. Probably a combination of some of the alternatives discussed in this statement could provide the energy required in the long run. Understanding the extent to which the alternatives may individually or collectively replace or complement the Crow Indian coal requires a knowledge of the characteristics of our total national energy system. The facts that are most relevant are outlined below:

(1) Energy requirements historically increase at about the same growth rate as the gross national product.

(2) Energy requirements can be reduced and constrained to some degree through the price mechanism in a free market or by more direct constraints.

(3) Energy sources are not completely interchangeable.

(4) A broad spectrum of research and development is being directed to energy conversion--more efficient nuclear

reactors, coal gasification and liquefaction, liquified natural gas (LNG) and oil-shale retorting among others.

(5) Major potentials for filling the supply/demand imbalance for domestic resources are:

(a) More efficient use of energy

(b) Environmentally acceptable mining, processing, utilizing, and rehabilitation systems that will permit production and use of larger volumes of domestic coal.

(c) Accelerated exploration and developments and increased production from all domestic oil and gas resources.

(d) Development of the nation's oil shale resources.

Of the foregoing, increased domestic oil and gas production is the most promising, since indicated and undiscovered domestic resources total some 417 billion barrels of oil and 2,100 trillion cubic feet of gas. These resources are believed to be recoverable under current technology. However, the feasibility of providing adequate incentive and reducing the uncertainties inherent in petroleum exploration is not known.

(6) The acceptability of oil and gas imports as an alternative is diminished by:

(a) The recent disparity between costs of foreign and domestic oil.

(b) Apparent high costs of liquefying and transporting natural gas other than overland by pipeline.

(c) The national security risks inherent in placing reliance for essential energy supplies on politically unstable foreign sources, particularly those that are prone to interrupt the flow of petroleum in order to exert economic and political pressure on their customers.

(d) The aggravation of unfavorable international trade and payments balances which would accompany substantial increases in oil and gas imports.

In view of the trends and problems discussed above , it seems reasonable to postulate that for some time to come the best alternative to the production of coal from the Crow Indian coal resource area would be to produce an equivalent amount of similar coal from elsewhere in Montana, Wyoming, or North Dakota.

ENERGY CONSERVATION ALTERNATIVES

The United States has the highest per capita consumption of energy and the highest per capita income of all the countries in the world. Demand for energy in the U. S. has increased at an average rate of 3.1 percent annually for the last twenty years, more than twice the growth rate of the U. S. population. The standard of living and GNP have both been correlated to energy consumption. In the past, growth of energy consumption has not been materially constrained by price or supply of energy resources. Nor can reduction in population growth materially affect future growth of energy consumption. Only through lower energy use on a per capita basis can this be accomplished. Due to the uncertainty of long-term energy supplies, the probable inclusion of environmental and political costs in the price of energy, and the concern over environmental quality, it is possible that the rate of future increases in energy use on a per capita basis will be affected.

The most promising approaches to reduction in per capita energy use are (1) reduction in the growth rate of demand for energy-produced goods and services, (2) more energy efficient methods in the production of goods and services, and (3) more efficient energy conversion processes. Examples of measures that can be utilized to reduce the rate of growth of per capita energy demand under the above categories include (1) increased use of mass transit and a trend toward smaller automobiles, (2) additional use of insulation in new and existing buildings to reduce energy requirements for heating and air conditioning, and (3) technological advances in the extraction of energy from fuels.

The Office of Emergency Preparedness (OEP) found the greatest potential for energy conservation is in (1) improved insulation in homes, (2) adoption of more efficient air-conditioning systems, (3) shifting of intercity freight from highway to rail, intercity passengers from air to ground travel, urban passengers from automobiles to mass transit, and freight consolidation in urban freight movement, and (4) introduction of more efficient industrial processes and equipment.

The kind of public policies that would be required to reduce energy demand, according to Michael McCloskey, Executive Director of the Sierra Club, would include the replacement of the market system with a detailed control on the production, importation, and use of energy in all sectors and regions of the economy to determine how much energy shall be produced or imported and who shall consume energy.

An additional method of reducing overall demand for energy is to limit economic growth. The theory of zero economic growth to preserve the environment has been suggested as a viable alternative to increased energy consumption.(59) However, future expansion of the labor market will be needed to accommodate those persons willing and able to enter it. The only means of accomplishing this is to increase the GNP, which at present correlates with increased energy consumption. In essence, the economy must expand to provide the needed jobs, goods and services. However, a zero growth approach would probably severely limit the opportunities available for disadvantaged members of our society unless major restructuring of our economic system was implemented.

In December 1973, the Federal Energy Administration was created to centralize all energy policy planning and to manage Federal fuel allocation, conservation and perhaps rationing. This agency incorporated energy office units of the Department of Interior, Cost of Living Council, and Office of Management and Budget.

Development of untapped energy sources and more efficient methods of energy conversion offer long-range possibilities for conservation of scarce nonrenewable resources. Long-term sources such as geothermal steam, tar sands, hydrogen and solar energy, and conversion techniques such as fuel cell and magnetohydrodynamics are discussed elsewhere in this chapter.

The environmental benefits of energy conservation depend on the energy mix that evolves. Reduced consumption of energy from one or several sources may be balanced by increased consumption of energy from other sources. Environmental changes will vary in direct proportion to the types of impacts resulting from the new pattern of consumption compared to those from the old pattern.

CHAPTER IX

CONSULTATION AND COORDINATION WITH OTHERS IN PREPARATION OF DRAFT

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Other Federal Agencies

Consultation with other Federal agencies provided the BIA task force with data and general information which assisted in the timely preparation of this environmental impact statement. Several Federal agencies also reviewed the working draft of the statement.

The U.S. Geological Survey offices in Billings, Montana, provided coal reserve information as well as hydrologic data. They also were extremely helpful in providing review comments on draft material.

The Bureau of Sport Fisheries and Wildlife personnel provided substantive amounts of data for the wildlife inventory and the expected impacts on wildlife from coal development.

The Soil Conservation Service offices in Billings and Hardin, Montana, provided soils and sedimentation data.

The Bureau of Mines in Denver, Colorado, supplied mineral inventory data.

Hydrologic data and informal review and consultation on the statement was received from the Bureau of Reclamation, Billings, Montana.

The Environmental Protection Agency, Denver, Colorado, and the Bureau of Land Management, Billings, Montana, provided informal review and consultation during the early stages of the statement preparation.

State Agencies

The Montana Department of State Lands provided extremely helpful review of early draft material.

The Bureau of Mines and Geology Offices at Billings and Butte, Montana supplied hydrologic and mineral data.

The Department of Natural Resources Office at Helena, and the Oil and Gas Commission Office at Billings supplied resource and mineral data.

The Air Quality Bureau supplied air quality information and standards.

Montana Fish and Game Offices at Helena and Billings were contacted regarding game counts and hunting use.

Consultants:

Mr. Joe Rawlins, a geologist from Billings, Montana, was consulted on the subject of mineral reserves in the area under study.

Mr. R. J. Brown, a consulting chemist, also from Billings, provided information regarding the soil chemistry, the coal analyses, and the chemistry of acid mine drainage.

Burlington Northern Railroad officials from Billings consulted with task force members on matters of railroad spur construction and location.

Crow Indian leaders participated before and during the preparation of the statement. The Crow Minerals Committee also reviewed an earlier draft and submitted comments for suggested changes.

APPENDIX SECTION

GLOSSARY

Acre-foot. The quantity of a material that will cover 1 acre or land 1 foot deep.

Alluvium. Clay, silt, sand, and gravel, or other rock material transported by flowing water and deposited as sorted or semi-sorted sediments.

Aquifer. A layer of rock that contains water and that will deliver it in usable quantities to wells.

Backfill. The process or filling and/or the material used to fill a surface mine pit.

Box cut. The initial pit in a strip mine where no open side exists; this results in a highwall on both sides of the pit.

Btu. Abbreviation for the British thermal unit. Amount of heat needed to raise the temperature of 1 pound of water 1 degree F. (252 calories).

Clinker. A fused or partly fused rock resulting from the burning of coal under shallow cover.

Coal. A solid, brittle, dark-brown to black, usually stratified, combustible, carbonaceous rock, formed by the partial to complete decomposition of vegetation.

Coke. Coal from which volatile constituents have been driven off by heat, so that the fixed carbon and ash are fused together.

Colluvium. Loose unconsolidated clay, silt, sand, and gravel at the foot of a slope, brought there by force of gravity.

Coulee. A steep-walled valley or ravine varying widely in size and often having a stream at the bottom.

Crop out. To be exposed at the surface.

Dead weight ton. Cargo capacity in long tons (2,240 pounds).

Dip. The angle at which a bed or stratum is inclined from the horizontal.

Effluent. A liquid or gaseous product discharged from the ground or a process.

Formation. A formation is a lithologically distinctive group of rocks selected as a convenient unit for mapping, description, and reference.

Ground water. Atmospheric water which saturates rock openings at and beneath the water table. Also used to mean all water below the ground surface.

Highwall. The unexcavated face of exposed overburden and coal in a strip mine pit.

Lignite. A brownish-black coal in which the alteration of vegetable material has not progressed as far as subbituminous coal.

Long ton. A ton weighing 2,240 pounds.

Member. A division of a formation generally of distinct lithology.

Overburden. Rock or unconsolidated material overlying a coal bed, excavated during strip mining.

Passerine. Small or medium-sized, chiefly perching song birds, having grasping feet with the first toe directed backwards.

Phytotoxic. Poisonous to plants.

Potentiometric surface. A surface which represents the static head of a fluid in a stratum as related to an aquifer; it is defined by the levels to which water will rise in tightly cased wells.

Proximate analysis. The determination of the compounds in a coal.

R. Range, one of the north-south rows of townships in a U. S. public-land survey.

Raptorial. An order of birds including all the birds of prey such as the eagle, hawk, owl, and vulture.

Reserves. Known deposits of coal that can be profitably mined. Tonnage generally known within 20 percent.

Resources. Includes reserves and other coal deposits that may become profitable to mine. Tonnage imperfectly known.

Sandstone. A cemented or compacted detrital sedimentary rock composed usually of grains of quartz.

Section. A piece of land that is 1 square mile or 640 acres.

Shale. A laminated sedimentary rock in which the particles are predominately clay size.

Short ton. A unit of weight that equals 2,000 pounds.

Siltstone. A sedimentary rock composed of grains intermediate in size between clay and sand.

Slope wash. Soil and rock material that has been moved down a slope by gravity and running water. Not concentrated in a channel.

Slurry. A mixture of fine coal in water. Commonly pumped through pipelines at processing plants or to consumption points.

Soil Material. Soils leached free of soluble salts and capable of sustaining plant growth, and recognized as such by standard authorities.

Spoil. The overburden removed in strip mining. Debris or waste material from a strip mine.

Subbituminous coal. Nonagglomerating coal having a heat value of 8,300 to 13,000 Btu on a moist, mineral-matter-free basis. Intermediate in rank between lignite and bituminous coal.

T. Township, a piece of land that is bounded on the east and west by meridians 6 miles apart at its south border, has a north-south length of 6 miles and forms one of the chief divisions of a U. S. public-land survey.

Unit train. A train made up entirely of coal cars carrying coal directly from the loading place to point of delivery.

Working pit. The place at a mine from which the coal is actually being extracted.

SOME ABBREVIATIONS AND SYMBOLS USED

Ac	acre
AC/AUM	acres per animal unit month
AEC	Atomic Energy Commission
AF	acre foot or feet
AUM	animal unit month
bbl	barrel
bd ft	board foot or feet
BIA	Bureau of Indian Affairs
Btu	British thermal unit
bu	bushel(s)
C	clay, carbon, centigrade
cfd	cubic feet per day
CFR	Code of Federal Regulations
cfs	cubic feet per second
CH_4	methane
CL	clay loam
CO	carbon monoxide
CO_2	carbon dioxide
COED	char-oil-energy-development
COG	coal-oil-gas
CSF	Consul synthetic fuels
CSG	crest-stage gage
dB	decibel
DWT	dead weight ton
EHV	extra high voltage
EIS	environmental impact statement
EPA	Environmental Protection Agency
F	fahrenheit, fluorine
Fe_2O_3	ferric oxide
FeS_2	iron pyrite
FPC	Federal Power Commission
ft^3/hr	cubic feet per hour
GNP	gross national product
gpm	gallons per minute
H	hydrogen
H_2	hydrogen
HCN	hydrogen cyanide, hydrocyanic acid.
H_2O	water
H_2SO_3	sulfurous acid
H_2SO_4	sulfuric acid
kw	kilowatt
KWH	kilowatt hour
L	loam
lb	pound

LFS	loamy fine sand
LNG	liquefied natural gas
M	1,000
MgCaO	magnesium calcium oxide
$MgCO_3CaCO_3$	dolomite
MHD	magnetohydrodynamics
ug/m^3	micrograms per cubic meter
MM	million
MW	megawatt
N	nitrogen
N_2	nitrogen
NEB	National Energy Board
NO_x	nitrogen oxide
OSHA	Occupational Safety and Health Administration
pH	potential of hydrogen
ppb	parts per billion
ppm	parts per million
psi	per square inch
R	Range
Rs	Ranges
SAR	sodium adsorption rate
SC	sandy clay
scf	standard cubic foot or feet
SCS	Soil Conservation Service
Sec	section
Secs	sections
SiCL	silty clay loam
SiL	silt loam
SL	sandy loam
SNG	synthetic natural gas
SO_2	sulfur dioxide
SO_3	sulfite
SO_x	sulfur oxide
SRC	solvent-refined coal
T	Township
Ts	Townships
10^6	1,000,000
UHV	ultra high voltage
U_3O_8	uranium oxide
USC	United States Code
v	versus
VLCC	very large crude oil carrier
vs	versus

atm	atmosphere(s)
BN	Burlington Northern
$CaCO_3$	calcium carbonate, lime, limestone
CB & Q	Chicago, Burlington, and Quincy
Cl	chlorine
CO_3	carbonate(s)
CRG	Catalytic rich process
Fe	iron
F-T	Fischer-Tropsch
hp	horsepower
hr	hour
H_2S	hydrogen sulfide
K	potassium
kg	kilogram(s)
m	meter(s)
Mcf	thousand cubic feet
Mg	magnesium
µg/l	microgram(s) per liter
Na	sodium
NEPA	National Environment Protection Administration
NGPRP	Northern Great Plains Resource Program
NO_3	nitrate(s)
NP	Northern Pacific
OEP	Office of Energy Preparedness
Rge.	Range
RR	railroad
sec	second(s)
SiO_2	silica
SO_4	sulfate(s)
tcf	trillion cubic feet

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Appendix A

RELATIONSHIP OF COAL MINED TO POWER GENERATED

A. Power Generation:

1. Assumptions:

   a. Assume Power Station Heat Rate = 9000 BTU /KWH (with no other adjustments for efficiency)

   b. Assume Coal Heating Values can be:
   (1) 7000 BTU/lb
   (2) 9000 BTU/lb
   (3) 11,000 BTU/lb

   c. Assume Mining Rates can be:
   (1) 8,000,000 tons/yr
   (2) 5,000,000 tons/yr
   (3) 1,000,000 tons/yr

2. Computations:

   a. For 7000 BTU coal

$$7000 \text{ BTU/lb} = 14 \times 10^6 \text{ BTU/ton}$$

(1) For 8,000,000 tons/yr mined

$$\frac{14 \times 10^6 \text{ BTU/ton} \times 8 \times 10^6 \text{ ton/yr}}{9 \times 10^3 \text{ BTU/KWH} \times 8.76 \times 10^3 \text{ hrs/yr}} = 1.42 \times 10^6 \text{ kilowatts}$$

(2) For 5,000,000 tons/yr mined

$$\frac{14 \times 10^6 \times 5 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 0.89 \times 10^6 \text{ kilowatts}$$

(3) For 1,000,000 tons/yr mined

$$\frac{14 \times 10^6 \times 1 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 0.18 \times 10^6 \text{ kilowatts}$$

   b. For 9000 BTU coal

$$9000 \text{ BTU/lb} = 18 \times 10^6 \text{ BTU/ton}$$

(1) For 8,000,000 ton/yr mined

$$\frac{18 \times 10^6 \times 8 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 1.83 \times 10^6 \text{ kilowatts}$$

(2) For 5,000,000 tons/yr mined

$$\frac{18 \times 10^6 \times 5 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 1.14 \times 10^6 \text{ kilowatts}$$

(3) For 1,000,000 tons/yr mined

$$\frac{18 \times 10^6 \times 1 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 0.23 \times 10^6 \text{ kilowatts}$$

c. For 11,000 BTU coal

11,000 BTU/lb = 22 x 10^6 BTU/ton

(1) For 8,000,000 tons/yr mined

$$\frac{22 \times 10^6 \times 8 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 2.23 \times 10^6 \text{ kilowatts}$$

(2) For 5,000,000 tons/yr mined

$$\frac{22 \times 10^6 \times 5 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 1.39 \times 10^6 \text{ kilowatts}$$

(3) For 1,000,000 tons/yr mined

$$\frac{22 \times 10^6 \times 1 \times 10^6}{9 \times 10^3 \times 8.76 \times 10^3} = 0.28 \times 10^6 \text{ kilowatts}$$

Appendix B

EPA AMBIENT AIR QUALITY STANDARDS AND ALLOWABLE EMISSIONS

Substance	Ground Level Air Quality Standards		Max. Emission Rate
	Primary	Secondary	
	in micrograms per cubic meter (g/m^3)		in lbs per million BTU coal imput to burners
Particulate Matter			
Annual Geometric mean	75	60	
24 Hour Concentration to be exceeded more than once a year	260	150	
Emission			0.10
Sulfur Dioxide			
Annual arithmetic mean concentration - micograms per cubic meter	80	60	
24-hour concentration not to be exceeded more than once per year - micrograms per cubic meter	365	260	
One-hour average not to be exceeded in any 24-hour period - micrograms per cubic meter		1,300	
Emission			1.20
Nitrogen Oxides			
Annual arithmetic mean	100	100	
Emission			0.70
Carbon Monoxide			
Maximum eight-hour concentration not to be exceeded more than once per year.	10,000	10,000	

Substance	Ground Level Air Quality Standards		Max. Emission Rate
	Primary	Secondary	
Maximum one-hour concentration not to be exceeded more than once per year.	40,000	40,000	
Hyrdrocarbons			
Maximum three-hour concentration between 6:00 and 9:00 a.m. not to be exceeded more than once per year.	160	160	

Note: Primary standards protect health; secondary standards protect public welfare.

APPENDIX C

A RESOLUTION PROVIDING GENERAL DIRECTION ON MATTERS CONCERNING PENDING COAL DEVELOPMENT ON TRIBALLY OWNED COAL RESOURCES AND ON ALL COAL RESOURCES WITHIN BOUNDARIES OF THE CROW INDIAN RESERVATION.

WHEREAS, by its rejection on June 24, 1974, of the amended leases between the Crow Tribe of Indians and Westmoreland resources, the Crow Tribal Council expressed its deep concern about the implications of pending development of tribally owned coal resources and its strong desire that said development be done in an orderly manner with the insurance that the Crow Tribe receive all the economic, financial and environmental advantages to which it its entitled; and

WHEREAS, in addition to the above concern, there is a concern about any development of coal resources within the boundaries of the Crow Indian Reservation; and,

WHEREAS, Pursuant to Resolution 74-09, only the Crow Tribal Council by a majority vote on a resolution can authorize prospecting permits, leases, or any other instrument which would permit the prospecting for any of the said minerals or the leasing or sale of the same, and until such resolution is passed and approved, ANY INSTRUMENT relating to the minerals of the Crow Tribe, including coal, and other hydrocarbons excluding oil and gas is INEFFECTIVE FOR ANY PURPOSES; and,

WHEREAS, Resolution 74-17 authorized the Mineral Committee to take certain actions designed to protect the TREATY MINERAL RIGHTS of the Crow Tribe as well as to protect the economic, human, and environmental resources of the Crow Reservation and Crow People; and,

WHEREAS, Investigation conducted thus far has convinced said Mineral Committee that the Department of the Interior, Bureau of Indian Affairs, and other federal agencies HAVE NOT acted in a manner consistent with, and for the best interests of, the Crow Tribe of Indians in regard to protecting the human and natural resources of CROW COUNTRY ; and,

WHEREAS, there is a need to identify and coordinate all issues relating to orderly coal development, including buy not limited to the economic, financial, social, legal and environmental aspects of such developments;

SO, THEREFORE BE IT RESOLVED by the Crow Tribal Council, as the ONE AND ONLY VOICE OF THE CROW PEOPLE, in a council Meeting duly called and assembled, a quorum being present, that;

1. All coal mining leases, whether existing or pending are hereby declared null and void, illegally obtained by the coal companies, oil corporations, individuals, or other entities, and are of no effect what-so-ever, PURSUANT TO THE CROW TRIBAL CONSTITUTION AND ARTICLE 1, SECTION 8 OF THE CROW TRIBAL BY-LAWS; the laws of the United States; and the Code of Federal Regulations. Furthermore, any actions by the Interior Department or any of its agencies taken in behalf of the Crow Indian Tribe, whether past, present, or future which are not consistent with the Crow Tribal Constitution and Article 1, Section 8 of the Crow Tribal By-Laws are hereby declared unlawful, null and void, and in no way binding upon the Crow Tribe of Indians.

2. A green Belt Zoning Moratorum on all lands within the exterior surface boundaries of the Crow Indian Reservation is hereby declared on all activity

related in any way to the mining of coal, said Moratorum to be in effect for 6 months further directive from the Crow Tribal Council.

3. The 2,560-acre limitation for Crow Coal Mining Leases as contained in 25 CFR 173 are hereby declared to be the regulations to adhere to the event there is to be coal leasing and/or mining of Crow Indian Coal Lands.

4. The Crow Tribal Mineral Committee, Tribal Chairman and Secretary, and Tribal Attorneys are authorized to take any and all steps necessary to carry out the Crow Tribal Council Directives as set forth in this and Resolutions 74-09, 74-17, and 74-21.

5. Recognizing the SUPREMACY OF THE CROW TRIBAL COUNCIL IN voicing any and all decisions of the CROW PEOPLE, it is therefore declared that only, the Tribal Council can speak for the Crow Tribe of Indians in matters relating to the prospecting for, the leasing of, or the sale of Crow Tribal Minerals including coal, and other hydrocarbons, excluding oil and gas as stated in Article 1, Section 8 of the Crow Tribal By-Laws.

6. BE IT FURTHER RESOLVED that the Minerals Committee is hereby directed to coordinate and identify the various questions relating to coal development including buy not limited to, the economic, financial, social, legal and environmental aspects of such development and to present the plan or recommendations to the Council at the next quarterly Council meeting or at a special Council meeting or at a Special Council meeting called for that purpose.

PASSED, APPROVED AND ADOPTED by the Crow Tribal Council this 13 day of July 1974, by unanimous votes for, and ______ votes against passage, approval, and adoption.

(Signed) PATRICK STANDS OVER BULL
PATRICK STANDS OVER BULL, CHAIRMAN
CROW TRIBAL COUNCIL

ATTEST:

(Signed) TYRONE TEN BEAR
TYRONE TEN BEAR, SECRETARY
CROW TRIBAL COUNCIL

(Signed) GEORGE A. LAVERDURE
SUPERINTENDENT, CROW INDIAN
RESERVATION

APPENDIX D-1 SOIL ASSOCIATIONS

Map 7 in Chapter II shows seven soil associations in the Crow coal resource area, numbers 8, 9, 11, 12, 13, 14, and 16. See the map for their names and areal extent. The following discussion is in two parts:

- o Description and capabilities of the soil associations and their member soil series and their capabilities in the reclamation of strip-mined areas.
- o Each of these two parts is discussed by area--permit or lease areas on the reservation and the ceded area outside the reservation.

Description and Capabilities

In the Shell lease area all the soils are within the Wayden-Regent association (number 16 on the association map). The MRBI soil survey of the area after correlation by the Soil Conservation Service has 31 soil mapping units within the area proposed for strip mining in the Shell permit area.

The Wayden-Regent-shale outcrop association is formed on gently undulating to very steep sedimentary plains in the 15- to 19-inch precipitation zone. In this association, the Wayden series makes up about 40 percent, the Regent series 25 percent, and minor soils and shale outcrops 35 percent of the area.

Wayden soils are on the steeper and broken slopes and are usually 15 to 20 inches deep overlying unweathered shale. The surface layer is only a few inches thick and grades into a grayish brown silty clay loam.

The water-holding capacity of this soil is low because of its limited depth. The soil's use is limited to grazing.

The Regent soils are on the gently undulating to hilly ridge crests above the Wayden soils. These soils are usually about 26 inches deep overlying shale. The water-holding capacity of the Regent soil is moderate, and the soils are arable if in areas large enough to justify farming operations.

Minor soils in this Association are Lennep, Nunn, Heldt, and Doney series. Nunn and Heldt soils are deep alluvial soils in the valleys. They have a high water-holding capacity and are excellent for agricultural purposes. The Lennep soil is in close association with sodium, which adversely affects the permeability, water-holding capacity and productivity of this soil. The Doney soil is somewhat shallower, more permeable, younger, and less developed than Regent series.

In the Gulf permit area, the Ringling - Searing - Arnegard Association of soils (number 13 on the association map) is usually present. This association occupies gently sloping to steep alluvial fans, footslopes and sedimentary plains. Approximately 30 percent of the area is Ringling, 20 percent Searing and 15 percent Arnegard series. The remaining 35 percent of the landscape consists of minor soils and rock outcrops.

Ringling soils are on rolling to very steep topography. This soil, to a depth of 12 to 14 inches, is reddish brown channery loam and overlies raw shale. Grazing is the best use for these soils.

Searing soils are formed on the smoother landscapes adjoining the Ringling soils. They have a surface layer with an average depth of 6 inches, which is a dark reddish gray loam. The subsoil is about 18 inches deep and is reddish brown loam and clay loam grading to weathered shale and sandstone at a depth of about 20 inches. This soil is used for improved pasture and small grains as well as rangeland.

The Arnegard series includes deep loamy alluvial soils on the fans and footslopes. They have a dark grayish brown loam surface about 14 inches thick. The subsoil is dark grayish brown clay loam about 17 inches thick and is underlain by dark brown clay loam and loam. This soil usually extends to a depth of over 5 feet. This excellent highly productive soil is used for improved pasture and small grains as well as rangeland.

Minor soils in this association are in the Wages, Nunn, Reeder, Doney and Grail series.

The Peabody permit is an area of gently to strongly rolling weathered sandstone and deep to moderately deep soils. Most of the soils are sandy in texture and are well to excessively drained. Due to this excessive drainage, the soil profiles are generally well leached of soluble salts. The Nelson-Alice association (number 8 on the association map) is the major one. They occupy moderately steep footslopes, fans, and sedimentary plains.

The Nelson series comprises about 55 percent, Alice 25 percent, and minor soils 20 percent of the area. Due to the drouthy, erosive nature of these soils, grazing is the highest and best use.

Nelson soils are on undulating to rolling sedimentary plains. The surface layer typically is light olive brown and grayish brown fine sandy loam about 5 inches thick. This in turn is underlain by light olive brown and grayish brown fine sandy loam about 5 inches thick. It is underlain by light brown or light yellowish brown grading to pale yellow sandy loam. Sandstone is usually at a depth of 30 inches.

Alice soils are on sloping to moderately steep topography on footslopes, fans and valley bottoms. The surface layer typically is grayish brown fine sandy loam about 2 inches thick. The subsoil is grayish loam and light to olive brown sandy loam and loamy sand which extends to a considerable depth.

The minor soils in this association are in the Travessilla, Thedalund, Tullock, and Terry series.

Most of the soils in this association are deep and sandy and leached of excessive salts.

In the ceded area, three soil associations are present. They are the Nelson-Alice (formerly called Flasher-Bainville), the Wibaux-Thedalund-Spearman (number 12 on the association map) and the Thedalund-Midway (number 11 on map, formerly called Bainville-Midway) associations.

The Nelson-Alice Association has already been described for the Peabody permit area. In the Thedalund-Midway Association, Thedalund and Midway soils each make up about 30 percent of the area, and minor soils and shale and sandstone outcrops make up 40 percent. The minor soils include the McRae, Fort Collins, Thurlow, Cushman, and Nelson series. Range is the principal use.

The Wibaux-Thedalund-Spearman Association is the one surrounding the Westmoreland Resources mining operation and is described to some extent in FES-74-8. The composition is about 30 percent Wibaux, 20 percent Thedalund, 20 percent Spearman, and 30 percent minor soils. The minor soils include Nelson, Cushman, Hydro, McRae, and Fort Collins.

Reclamation Capabilities

In the Shell leasehold most of the area proposed for strip mining is within the 15- to 19-inch precipitation zone. The topography is gently to strongly sloping, dissected sedimentary plains. The Wayden soils would not provide adequate usable topsoil for reclamation purposes.

The Regent soil would provide sufficient surface material for reclamation purposes.

The deep alluvial soils of the valleys would provide a surplus of usable surface material for reclamation. The areas that may prove most feasible for strip mining are largely in the valleys where a surplus of surface material exists. Stockpiling the deep alluvial soils before mining begins should simplify later reclamation.

Montana State University conducted a series of soil tests from cores provided by the Shell Oil Company. Four of the cores were tested extensively to determine the physical and chemical characteristics of the overburden in the Youngs Creek area. Samples were tested in each 10-foot zone of the core. The samples were mixed so that an average for each 10-foot zone could be obtained. One core from hole No. 398 was continuous from 20' to 124' and a detailed evaluation of the reclamation capabilities was discussed. Unfortunately none of the cores taken included the top 20 feet, which is needed before mining begins. In general, the cores from hole No. 398 were quite stratified with lenses of siltstone, sandstone, and shale. Preliminary tests indicated that the lenses high in shales, and siltstone weathered into amorphous masses which were restrictive to water penetration, would cause reclamation problems. These materials often had high salinity readings as well as high clay contents.

Three zones, 30 to 40 feet, 50 to 60 feet, and 60 to 70 feet, would make good material for reclamation purposes. The two deeper zones were soft sandstone, low in salts, sodium and other inhibiting factors. In general, it was determined that most of the sandstones encountered had desirable reclamation characteristics, particularly the softer sandstones. Some of the hard sandstones present weathering problems and should not be used.

In general, it was determined from the limited number of cores tested that reclaimable soil material exists in the overburden above the upper coal seam. The tests indicated also that the overburden materials were much superior to the materials found by Hodder and Sindelar(42) at Decker, Montana, in 1972. The chief problem involved appears to be getting the desirable soil material to the top of the reformed spoil material. Soil tests of material from the surface to a depth of 20 feet should be run prior to mining the 20 feet nearest the surface to determine the reclamation characteristics. Preliminary indications are that extensive sandstone formations exist near the surface throughout the area. Where large volumes of sandstone low in salts are present reclamation would be relatively easy.

A detailed coring program should precede the mining, as the overburden is very stratified. Adequate soil investigations will be required to insure that the proper material is placed on the surface.

Native topsoil is thin over approximately 40 percent of the area, so the use of reclaimable overburden will be necessary.

All of the samples of the interburden material below the upper coal zone had high sodium readings and were generally impermeable. The interburden, therefore, should not be placed near the surface. Reclamation plans must face this problem if deeper coal seams are to be mined.

The tests indicated that most of the overburden was very low in plant nutrients. Nitrogen and phosphorus were particularly low in all of the tests.

The Montana State soil laboratory conducted a series of plant growth studies on the material from the cores and dramatic plant growth rates were noted. It was determined that yields were approximately doubled when fertilizer in the proper proportions and amounts was applied. An active fertilizer program would be necessary for successful reclamation.

In the Gulf permit area, the soils are developed in a 15- to 19-inch precipitation zone from interbedded sandstone and loamy shales. The Ringling series is deficient in topsoil for reclamation purposes. Most of the other soils in this association have sufficient topsoil for reclamation, especially the Arnegard series.

In the Gulf permit area, reclamation would have problems similar to those on the Shell lease. The topography is somewhat rougher and is scenic with much heavier timber stands.

Gulf has not done any soil testing in its initial exploratory work. It is anticipated that the deep soil probes will yield information similar to that for the Shell area. Extensive soil testing will be necessary before mining operations are proposed so that a reclamation plan can be developed.

In the Peabody permit, the soils are generally deep and therefore would provide an abundance of usable material for reclamation purposes.

The Thedalund soils would provide a minimum amount of usable material for topsoiling purposes. The Midway soils are too shallow to provide adequate material for topsoiling. In Midway areas, deep soil probes will have to be made to locate usable topsoiling material from deeper strata.

The ceded area is a land of gently to strongly rolling weathered sandstone, siltstone, and shale with some of the same topographical and soil characteristics as the Peabody permit area. The Nelson-Alice and Thedalund-Midway Associations have the same characteristics and management problems as in the Peabody area. In the Wibaux-Thedalund-Spearman association, some of the soils, like Fort Collins loam and Nunn silty clay loam, have adequate material for topsoiling. The shallow ones, like Wibaux, Thedalund, and Midway need to be supplemented with permeable material for selected layers in the overburden or from other areas.

An active fertilization program would be necessary as most of the sandy soils are low in inherent fertility. Fertilizers would probably give a dramatic response in plant growth.

APPENDIX D-2.

SOIL MAPPING UNITS [1/]

Soil Mapping Units			Slope					
BIA	SCS	Series and Type	Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
2A10/C	19C	Kyle SC	4 - 8				x	
2A19/B	260B	Marias C	2 - 4				x	
+2A19/B	260B	Marias C	2 - 4				x	
2A19/C	260C	Marias C	4 - 8			x	x	
+2A19/C	260C	Marias C	4 - 8				x	
2A19/D	260D	Marias C	8 - 15				x	
+2A19/D	260D	Marias C	8 - 15				x	
2bB36/A		(slowly permeable gley soils)	0 - 4				x	
2-14G19/C	360C	(Eltsac-Marias C)	4 - 8				x	
2-14G19/D	360D	(Eltsac-Marias C)	8 - 15			x	x	
C2A10/C	25C	Heldt SiCL	4 - 8	x				
+C2A10/C	25C	Heldt SiCL	4 - 8			x	x	
+C2A10/D	25D	Heldt SiCL	8 - 15		x	x	x	
C3A11/B	23B	Thurlow SiCL	1 - 4	x				
C3A11/C	23C	Thurlow SiCL	4 - 8	x			x	x
+C3xA13/C	13C	Lohmiller SiCL	4 - 8		x			
C3A20/A	45A	Nunn SiCL	0 - 1			x	x	
C3A20/B	45B	Nunn SiCL	1 - 4	x			x	
C3A20/C	45C	Nunn SiCL	4 - 8			x	x	x
C3A20/D	345D	Nunn-Midway SiCL	4 - 15		x	x	x	x
C3xA22/A	15A	Frazer SiCL	0 - 1			x		
MC3A20/A	144A	Grail CL	0 - 2			x	x	
MC3A20/B	144B	Grail CL	2 - 8			x	x	
C3A29/C	81C	Grail CL	2 - 8				x	

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS 1/

Soil Mapping Units BIA	Soil Mapping Units SCS	Series and Type	Slope Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
C3A29/D	81D	Grail CL	8 - 15				x	
MC3A29/B	344B	(Grail CL)	2 - 4				x	
MC3A29/C	344C	(Grail CL)	4 - 8				x	x
MC3A29/D	344D	(Grail CL)	8 - 15				x	
MC3w$_1$A36/B	244B	Grail CL, seeped	2 - 4				x	
C3x-27G14/C	313C	Lohmiller-Midway SiCL, undulating	4 - 15	x				
4A17/B	108B	Talag C	0 - 8	x				
4a$_2$A17/B	8B	Talag-Allentine complex	0 - 4	x				
4A26/B	73B	Lennep L	2 - 4		x	x	x	
4A26/C	73C	Lennep L	4 - 8			x	x	
4a$_2$A26/B	173B	Lennep-Adger complex, gently undulating	0 - 4			x		
5B17/B	177B	Hydro L	0 - 8	x				
5B17/C	177C	Hydro L	0 - 8	x				
5B26/B	74B	Belfield SiL, gently undulating	(1 - 4)		x	x	x	
5B26/C	74C	Belfield SiL, undulating	(4 - 8)			x	x	
6A10/C	421C	McRae L	4 - 8	x				
6A11/B	24B	Fort Collins L	2 - 4	x				
6A11/C	24C	Fort Collins L	4 - 8	x				
6A13/B	12B	Haverson L	2 - 4	x				
6A20/A	46A	Wages L	0 - 2			x		
6A20/B	46B	Wages L	2 - 4	x	x	x		

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS[1/]

Soil Mapping Units			Slope					
BIA	SCS	Series and Type	Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
6A20/C	46C	Wages L	4 - 8	x	x	x	x	
6A20/D	46D	(Wages-Thedalund complex)	8 - 15		x	x	x	
6A21/B	79B	(Shaak CL)	2 - 4			x		
6A21/C	79C	Shaak CL	4 - 8		x	x		
C6A21/C	153C	(Shaak FSL)	4 - 8		x	x	x	
6A22/A	14A	Korchea L	0 - 2			x		
6A29/C	446C	(Wages L)	4 - 8				x	
6A29/D	446D	(Wages L)	8 - 15				x	
+M6A20/A	92A	Arnegard SiL	2 - 4				x	
M6A20/B	92B	Arnegard SiL	2 - 4			x		
M6A20/C	92C	Arnegard SiL	4 - 8			x		
M6A29/C	392C	(Arnegard SiL)	4 - 8				x	
M6w$_1$A29/B	192B	Arnegard SiL	2 - 4			x	x	
M6w$_1$A29/C	192C	Arnegard	4 - 8			x	x	
M6w$_1$A29/D	192D	Arnegard L	8 - 15			x	x	x
6-C3bxA22/B	202B	Savage and Frazer Soils	0 - 4			x	x	
6-C3xw$_1$A13/B	3E	(The SCS correlated this mapping unit with saline land. Typically the unit is not saline.)	0 - 4	x				
6-C3xw$_1$A22/B	502B	Korchea & Frazer soils, water table	1 - 4			x	x	
6-C3xw$_2$A22/A	402A	Alluvial land, wet	0 - 2			x	x	

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS 1/

Soil Mapping Units			Slope					
BIA	SCS	Series and Type	Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
6B13/D	129D	Kim L	4 - 15	x				
+6B13/D	129D	Kim L	4 - 15		x			
6B13/E	129E	(Kim L)	15 - 35	x				
+6B13/E	129E	(Kim L)	15 - 35		x			
6D20/C	66C	(Wages L, upland phase)	4 - 8			x		
C7A10/C	838C	Alice FSL	4 - 15	x				
C7A19/B	365B	Parshall FSL	2 - 4			x	x	
C7A19/C	365C	Parshall FSL	4 - 8		x	x		
C7A20/C	164C	Ascalon SL	4 - 8		x	x		
C7-19F14/D	738D	Nelson-Alice FSL, rolling	8 - 20	x				
C7-19F23/D	168D	Dast-Parshall SL, rolling	8 - 15		x	x		x
13a$_2$s$_2$G26/C	726C	(Winnett complex, undulating)	4 - 8			x		
14G19/C	60C	Eltsac C, undulating	(4 - 8)				x	
+14G19/C	60C	Eltsac C, undulating	(4 - 8)				x	
14G19/D	60D	Eltsac C, rolling	8 - 15			x		
+14G19/D	60D	Eltsac C, rolling	8 - 15				x	
L14G23/D	133D	Pierre-Lismas C, rolling	8 - 15				x	
+L14G23/D	133D	Pierre-Lismas C, rolling	8 - 15				x	
15-MC3w$_1$A36/D	244D	(Grail CL complex, seeped)	(8 - 15)				x	x
C15G20/B	167B	Regent SiCL, gently undulating	2 - 4				x	
C15G20/C	167C	Regent SiCL, undulating	4 - 8				x	
C15G20/D	167D	Regent SiCL, rolling	8 - 15			x	x	
C15G29/C	267C	(Regent SiCL)	4 - 8				x	
C15G29/D	267D	(Regent SiCL)	8 - 15				x	

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS 1/

Soil Mapping Units			Slope					
BIA	SCS	Series and Type	Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
C15-18G20/C	237C	Reeder-Rentsac complex, undulating	(4 - 8)					x
C15-27G23/D	834D	Wayden-Savage SiCL, rolling	(8 - 20)			x	x	x
+C15-27G23/D	834D	Wayden-Savage SiCL, rolling	(8 - 20)				x	x
18G11/C	37C	Cushman L, undulating	(4 - 8)	x			x	
18G20/C	48C	Reeder L, undulating	(4 - 8)			x	x	
18G21/C	70C	Shaak CL	4 - 8			x		
18G21/D	70D	Shaak complex	4 - 15			x		
F18G29/B	148B	Morton SiL, undulating	4 - 8				x	
F18G29/C	148C	Morton SiL, undulating	4 - 8				x	x
F18G29/D	148D	Morton SiL, undulating	8 - 15				x	
18-30G22/D	248D	Doney-Reeder L, rolling	(8 - 15)		x	x	x	x
+18-30G22/D	248D		(8 - 15)				x	x
18M11/C	347C	Spearman L, undulating	(4 - 8)	x			x	
18M20/C	547C	Searing L, undulating	(4 - 8)			x	x	
18M29/C		(Searing L)	4 - 8			x		x
+18-30M14/D	462D	(Wibaux-Cushman complex)	8 - 15					x
18-30M23/D	547D	Searing-Ringling complex, rolling	8 - 15			x	x	x
+18-30M23/D	547D	Searing-Ringling complex, rolling	8 - 15			x	x	x
18-30G-M37/E	292E	(The SCS correlated this mapping unit as Searing loam, hilly. Other soils, deep to very shallow are included in the association)	(15 - 35)			x	x	x
C19F14/C	438C	Nelson FSL, undulating	(2 - 15)	x				
C19F20/C	64C	Vebar FSL, undulating	(4 - 8)			x	x	

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS [1/]

Soil Mapping Units BIA	 SCS	Series and Type	Slope Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
C19F20/D	64D	Vebar FSL, rolling	(8 - 15)		x	x		
C19F23/C	68C	Dast SL, rolling	(4 - 15)			x		
C19F23/D	68D	Dast SL, rolling	(4 - 15)		x	x	x	
C19F23/E	68E	Dast SL, hilly	(15 - 35)			x	x	
+F24F14/D	538D	Tullock LFS, rolling	(4 - 25)		x	x		
C27G14/C	34C	Midway SiCL, undulating	(2 - 8)					x
C27G14/D	34D	Midway SiCL, rolling	(8 - 15)					x
C27G14/F	134F	(Midway SiCL)	25 - 90				x	
C27G23/D	534D	Wayden SiCL, rolling	8 - 15		x		x	
27-14G19/D	460D	(Eltsac-Midway-Marias complex)	8 - 15				x	
+27-14G19/D	460D	(Eltsac-Midway-Marias complex)	8 - 15				x	
27-26G14/D	434D	Midway-Lismas complex, rolling	(8 - 15)	x	x		x	
+27-26G14/D	434D	Midway-Lismas complex, rolling	(8 - 15)		x	x	x	
27-26G14/E	434E	Midway-Lismas complex, hilly	(15 - 35)		x		x	
+27-26G14/E	434E	Midway-Lismas complex, hilly	(15 - 35)		x	x	x	
+27-26G23/E	534E	Wayden SiCL, hilly	(15 - 35)				x	x
27-30G13/D	636D	Thedalund-Fort Collins complex, rolling	(8 - 15)	x	x			
27-30G13/E	636E	(Thedalund-Midway-shale outcrop complex)	(15 - 35)	x	x			x
27-30G22/E	234E	Doney-Wayden complex,hilly	(8 - 35)		x	x	x	x
+27-30G22/E	234E		(8 - 35)				x	x
30G13/D	136D	(Thedalund L)	(8 - 15)	x				

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS [1/]

Soil Mapping Units								
BIA	SCS	Series and Type	Slope Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
30G13/E	136E	(Thedalund complex)	(15 - 35)				x	
30G13-F/E	536E	Thedalund-rock outcrop complex, hilly	(15 - 35)	x	x			
30G13-F/F	536F	Thedalund-rock outcrop complex, very steep	(35 - 90)	x				
30G22/D	1636D	Doney L, rolling	(8 - 15)		x	x	x	
30G22/E	1636E	(Doney L)	(15 - 35)		x		x	
30G22-F/F	1535F	(Doney-rock outcrop complex)	(35 - 90)			x	x	
30-6dB22/E	3229E	Bitton soils, hilly	(15 - 35)			x	x	
30-18G11/C	36C	Thedalund-Cushman L, undulating	(4 - 8)					x
30-18G21/D	170D	Shaak complex	4 - 15			x		
30-27G14/D	334D	Midway-Thedalund complex, rolling	(8 - 15)	x				
30-27G14/E	334E	Midway-Thedalund complex, hilly	(8 - 34)	x				
30G-M14/D	736D	Thedalund-Wibaux complex, rolling	(8 - 15)	x				
30G-M14/E	736E	Thedalund-Wibaux complex, hilly	(15 - 35)	x				
30G-M14/F	736F	Thedalund-Wibaux complex, very steep	(35 - 90)					x
30G-M23/D	1036D	Doney-Ringling complex, rolling	(8 - 15)				x	
30G-M23/E	1036E	Doney-Ringling complex, hilly	(15 - 35)		x	x	x	
+30G-M23/E	1036E	Doney-Ringling complex, hilly	(15 - 35)			x	x	x
30G-M23/F	1036F	Doney-Ringling complex, very steep	(35 - 95)			x	x	x

APPENDIX D-2 (cont.)

SOIL MAPPING UNITS [1]

Soil Mapping Units			Slope					
BIA	SCS	Series and Type	Range (%)	Peabody N	Peabody S	Crow Res.	Gulf	Shell
37-C19F14/D	638D	Nelson-Travessilla FSL, undulating	(8 - 20)	x				
+37-C19F14/D	638D	Nelson-Travessilla FSL, undulating	(8 - 20)			x		
47G/F	100F	Shale outcrop				x		

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[1] Soil mapping unit names in the Series and Type column enclosed in parentheses are supplied by the Planning Support Group and are not necessarily the correlated names of the Soil Conservation Service.

A complete description of all mapping units and their respective capability classes are available at the U. S. Soil Conservation Service Office, Hardin, Montana.

SOIL MAPPING UNITS IN CEDED AREA

Soil Mapping Units				Tract		
Big Horn County (field) (10)	Treasure County (Publ.) (10a)	Series and Type, or Mapping Unit Name 1,2/	Slope Range (%) 3/	2	3	5
838C	-	Alice FSL	4-15		x	
164C	-	Ascalon SL	4- 8		x	
300E	Ba	badlands	10-60+			x
74B	-	Belfield SiL	0- 1			x
147C	-	Chugter soils	4-15	x	x	x
37C	Cr	Cushman L	4- 8	x	x	x
24B	Fo	Fort Collins L	1- 4	x	x	x
24C	Fr	Fort Collins L	4- 8	x	x	x
124C		Fort Collins L, channeled	4- 8		x	
15A		Frazer SiCL	0- 1		x	x
529D		Harvey L, rolling	8-15	x		
12A		Haverson L	0- 2		x	
12B		Haverson L	2- 4		x	
	Ho	Haverson and Lohmiller soils /Havre and Lohmiller soils/	-			x
413A		Haverson and Lohmiller soils, frequently flooded	0- 1	x	x	
316A		Haverson and Lohmiller soils, wet			x	
25A		Heldt SiCL	0- 2		x	x
25B		Heldt SiCL	2- 4			x
25C		Heldt SiCL	4- 8		x	x
509B		Hydro-Allentine complex	1- 4			x
129D		Kim L	4-15		x	x

APPENDIX D-3 (cont.)

SOIL MAPPING UNITS IN CEDED AREA

Soil Mapping Units				Tract		
Big Horn County (field) (10)	Treasure County (Publ.) (10a)	Series and Type, or Mapping Unit Name 1,2/	Slope Range (%) 3/	2	3	5
14A		Korchea L	0- 2		x	x
114A	-	Korchea SiL	0- 2		x	
13B	-	Lohmiller SiCL	2- 4	x		x
13C	-	Lohmiller SiCL	4- 8	x	x	x
13D	-	Lohmiller SiCL	8-15	x	x	x
313D	-	Lohmiller-Midway SiCL, undulating	4-15	x	x	
21A	-	McRae L	0- 1	x		x
421B	-	McRae L	1- 4		x	
421C	-	McRae L	4- 8	x	x	x
421	Mk	McRae L	8-16			x
-	Mp	McRae & Haverson L /McRae & Havre L/	4- 8			x
-	Mm	McRae-Thedalund L /McRae-Bainville L/	/8-20/			x
34C	-	Midway SiCL, undulating	2- 8	x	x	x
34D	-	Midway SiCL, rolling	8-15		x	x
34F	Ms	Midway SiCL, hilly /Midway CL/	15-35			x
434D	-	Midway-Lismas complex, rolling	8-15	x		x
434E	Lf	Midway-Lismas complex, hilly /Lismas-Midway complex/	15-35			x
-	Mv	Midway-shale outcrop complex	30-70			x

APPENDIX D-3 (cont.)

SOIL MAPPING UNITS IN CEDED AREA

Soil Mapping Units						
Big Horn County (field) (10)	Treasure County (Publ.) (10a)	Series and Type, or Mapping Unit Name 1,2/	Slope Range (%) 3/	Tract 2	3	5
334D	-	Midway-Thedalund complex, rolling	8-15	x	x	x
334E	-	Midway-Thedalund complex, hilly	8-34	x	x	x
438C	Ff	Nelson FSL, undulating /Flasher FSL/	2-15 /4-20/	x	x	x
-	Fh	Nelson FSL, hilly /Flasher FSL/	20-35			x
-	Fm	Nelson? LFS /Flasher LFS/	/6-20/			x
738D	-	Nelson-Alice FSL, rolling	8-20		x	
638D	-	Nelson-Travessilla FSL, undulating	8-20	x	x	
45A	-	Nunn SiCL	0- 1		x	
45B	-	Nunn SiCL	1- 4	x	x	
45C	-	Nunn SiCL	4- 8	x	x	
345C		Nunn-Midway SiCL	4-15	x	x	
133	Pc	Pierre-Lismas C	/10-25/			x
35C	-	Renohill SiCL, undulating	4- 8	x		
69A	-	Richfield SiCL	0- 2		x	
69C	-	Richfield SiCL	4- 8	x		
3E	-	(The SCS correlated this mapping unit with saline land. Typically the unit is not saline.)			x	
134F	-	shale outcrop-Midway complex, steep	25-90	x		x

APPENDIX D-3 (cont.)

SOIL MAPPING UNITS IN CEDED AREA

Soil Mapping Units Big Horn County (field) (10)	Treasure County (Publ.) (10a)	Series and Type, or Mapping Unit Name 1,2/	Slope Range (%) 3/	Tract 2	Tract 3	Tract 5
347C	-	Spearman L, undulating	4- 8	x	x	x
462D	-	Spearman-Wibaux complex, rolling	4-15	x	x	x
108B	-	Talag C	0- 8		x	
129E	-	terrace escarpments, loamy	15-35	x	x	x
38C	-	terry FSL, undulating	4- 8	x		
636C	-	Thedalund L, undulating	4- 8	x	x	
36C	-	Thedalund-Cushman L, undulating	4- 8		x	
636D	-	Thedalund-Fort Collins complex, rolling	8-15	x	x	
336D	-	Thedalund-McRae L, dissected	4-35	x		x
136D	Bm	Thedalund-Midway complex, rolling /Bainville-Midway complex/	8-25 /8-15/		x	x
136D	Bn	Thedalund-Midway complex, hilly /Bainville-Midway complex/	8-25 /15-35/			x
136E	Bc	(Thedalund-Midway complex, hilly) /Bainville L/	15-35		x	x
836D	-	Thedalund-Nelson complex, rolling	4-15	x	x	x
536E	-	Thedalund-rock outcrop complex, hilly	15-35	x	x	x
536F	Bo	Thedalund-rock outcrop complex, very steep /Bainville-shale outcrop complex/	35-90 /30-70/	x		x

APPENDIX D-3 (cont.)

SOIL MAPPING UNITS IN CEDED AREA

Soil Mapping Units Big Horn County (field) (10)	Treasure County (Publ.) (10a)	Series and Type, or Mapping Unit Name 1,2/	Slope Range (%) 3/	Tract 2	3	5
736D	-	Thedalund-Wibaux complex, rolling	8-15	x	x	x
736E	-	Thedalund-Wibaux stony L, hilly	15-35	x	x	x
736F	-	Thedalund-Wibaux complex, very steep	35-90	x	x	x
23B	No	Thurlow SiCL /Nunn CL/	1- 4		x	x
23C	Nu	Thurlow SiCL /Nunn CL/	4- 8	x	x	x
123D	-	Thurlow-Midway SiCL	4-15	x	x	x
538D	-	Tullock LFS, rolling	4-25			x
40B	-	Vananda C	1- 8			x
46B	-	Wages L	2- 4		x	
46C	-	Wages L	4- 8	x		
-	Wr	Wibaux-rock outcrop	30-70			x
609C	Wt	Winnett complex,undulating	4- 8 /2- 8/			x

1/ Soil mapping units names in the Series and Type column enclosed in parentheses are supplied by the Planning Support Group and are not necessarily the correlated names of the Soil Conservation Service.

2/ Mapping unit names enclosed in / / marks are the ones used in "Soil Survey, Treasure County, Montana" (10a). Some of these names appear to be obsolete. The name to the left of or above the / / marks is the probable present day equivalent.

3/ Slope ranges if enclosed in / / marks are the ones used in the Treasure County soil survey.

APPENDIX D-4

CHARACTERISTICS OF SOME COMMON SOILS, THEIR PRODUCTIVITY, AND THEIR VALUE AS TOPSOILING MATERIAL IN RECLAIMING STRIP-MINED LAND

Soil Series and Texture 1/	Slope Range (%)	Depth	Parent Material	Permeability	Water-holding capacity (inches)	Elevation (feet)	Annual Precipitation (inches)	Mean Annual Soil Temp(^{o}F)	Frostfree Growing Season (Days)	Range Site 2/	Use 3/	Rating as Topsoiling Material
Adger C	0-8	deep 60''+	alluvium	slow	7-9	3,700 4,500	14-16	46-47	110-120	Ps	dry crop	very poor
Alice FSL	4-15	deep 60''+	alluvium	mod. rapid		2,900 3,700	13-14	47-49	115-125	Sy	dry hay	good
Arnegard SiL, L	2-35	deep 60''+	alluvium	mod.	8-10	3,500 4,800	14-17	44-46	100-115	Si, Sb	dry&irr. crop	excellent
Ascalon SL	4-8	deep 60''+	alluvium	mod.	8-10	3,000 3,800	13-14	46-47	110-115	Sy	dry crop	good
Belfield SiL	0-8	deep 60''+	alluvium loess	mod. slow	9-11	3,400 4,500	14-17	45-47	105-115	Si	irr.&dry crop	fair
Bitton grav. L	2-35	deep 50-60''	alluvium	rapid	3-6	3,300 3,800	14-16	46-47	110	Tsi	-	fair
Dast SL	8-90	mod. deep 30''	sandstone	mod. rapid	2-4	3,400 4,200	14-16	45-47	105-115	Sy, Tsy, Forest	-	fair
Doney L, SiCL	4-95	mod. deep 30''	shale, siltstone, sandstone	mod.	3-4	3,500 5,000	14-18	45-47	90-105	Si, Tsi	-	poor
Eltsac C, cobbly C.	4-35	mod. deep 30''	clay from shale	very slow	4-5	3,500 4,500	14-16	45-47	100-110	Cy	-	poor

APPENDIX D-4 (cont.) CHARACTERISTICS OF SOME COMMON SOILS, THEIR PRODUCTIVITY, AND THEIR VALUE AS TOPSOILING MATERIAL IN RECLAIMING STRIP-MINED LAND

Soil Series and Texture 1/	Slope Range (%)	Depth	Parent Material	Permeability	Water-holding capacity (inches)	Elevation (feet)	Annual Precipitation (inches)	Mean Annual Soil Temp(^{o}F)	Frostfree Growing Season (Days)	Range Site 2/	Use 3/	Rating as Topsoiling Material
Fort Collins L	0-15	deep 60''+	alluvium	mod.	9-11	2,850 3,400	12-14	47-49	115-125	Si	dry&irr. crop	excellent
Frazer SiCL, SiC	0-35	deep 60''+	recent alluvium	slow	10-12	-	14-16	45-47	105-120	Sb	dry&irr. crop	very good
Grail CL, SiC	0-35	deep 60''+	alluvium	mod. slow	8-10	3,500 5,000	14-17	45-47	100-115	Cy, Sb	dry&irr. crop	very good
Haverson L, SiCL, Sic	0-35	deep 60''+	recent stratified alluv.	mod. to mod. slow		2,800 3,300	12-14	47-49	115-125	Si, Ov	dry&irr. crop	very good
Heldt SiCL, SiC	0-15	deep 60''+	alluvium	slow		2,800 3,500	12-14	47-49	115-125	Cy	dry&irr. crop	good
Hydro L, SiL, SiCL	0-8	deep 60''+	alluvium	slow	9-11	3,000 3,800	13-15	47-49	110-120	Si	dry&irr. crop	fair
Kim L	4-15	deep 60''+	limy alluvium	mod.		2,900 3,500	13-14	48-50	115-125	Si	dry crop	good to very good
Korchea L, SiL, SiCL	0-35	deep 60''+	recent strat. limy alluvium	mod.	10-12	3,300 4,300	14-17	45-47	105-115	Sb	dry&irr. crop	very good
Kyle SiC, grav. Sic, C	0-15	deep 60''+	alluvium	very slow	7-9	3,000 3,800	13-14	47-49	110-125	Cy	dry&irr. crop	fair to poor
Lennep L	2-8	deep 60''+	alluvium	slow	9-11	3,500 4,300	14-16	45-47	95-115	Cy	dry&irr. crop	fair

APPENDIX D-4 (cont.)

CHARACTERISTICS OF SOME COMMON SOILS, THEIR PRODUCTIVITY, AND THEIR VALUE AS TOPSOILING MATERIAL IN RECLAIMING STRIP-MINED LAND

Soil Series and Texture 1/	Slope Range (%)	Depth	Parent Material	Permeability	Water-holding capacity (inches)	Elevation (feet)	Annual Precipitation (inches)	Mean Annual Soil Temp(^{o}F)	Frostfree Growing Season (Days)	Range Site 2/	Use 3/	Rating as Topsoiling Material
Lismas C grav. C	4-35	shallow 10-20"	shale	slow to very slow	2-3	3,000 3,800	12-14	47-50	105-125	SwC	-	unsuitable
Lohmiller SiCL	0-35	deep 60"+	limy recent alluvium	mod. slow	9-11	2,800 3,600	12-14	47-49	115-125	Cy, Ov	irr.&dry crop	good
Marias C	0-15	deep 60"+	alluvium	very slow	7-9	3,600 4,200	14-16	44-46	95-115	Cy	irr.&dry crop	fair to poor
McRae L, SiCL	0-35	deep 60"+	alluvium	mod.	10-12	2,800 3,800	12-14	47-49	115-125	Si	irr.&dry crop	excellent
Midway SiCL	2-35	shallow 15"	shale	slow	1-3	3,000 4,000	12-14	47-49	105-115	Cy, Tcy	-	poor
Morton SiL	4-8	mod. deep 36"	siltstone	mod.	6-7	4,500 5,200	16-18	44-46	85-95	Si	dry crop	good
Nelson FSL	4-15	mod. deep 30"	sandstone	mod. rapid	3-5	3,000 3,800	13-14	48-50	115-125	Sy	-	good
Norbert C	15-50	shallow 20"	shale	very slow		3,300 4,200	14-16	45-47	95-115	SwC	dry crop	unsuitable
Nunn SiCL	0-15	deep 60"+	alluvium	slow	8-10	3,300 3,700	14-15	46-47	105-120	Cy	dry crop	good

APPENDIX D-4 (cont.)

CHARACTERISTICS OF SOME COMMON SOILS, THEIR PRODUCTIVITY, AND THEIR VALUE AS TOPSOILING MATERIAL IN RECLAIMING STRIP-MINED LAND

Soil Series and Texture 1/	Slope Range (%)	Depth	Parent Material	Permeability	Water-holding capacity (inches)	Elevation (feet)	Annual Precipitation (inches)	Mean Annual Soil Temp(°F)	Frostfree Growing Season (Days)	Range Site 2/	Use 3/	Rating as Topsoiling Material
Parshall FSL	4-15	deep 60''+	alluvium	mod. rapid	8-10	3,400 3,800	14-16	46-47	100-115	Sy	dry crop	good
Pierre C	2-35	mod. deep 20-40''	shale	very slow	3-5	3,000 3,800	13-14	47-49	100-125	Cy	dry crop	poor
Reeder L	2-35	mod. deep 30''	mixed shale & sandstone	mod.	4-6	3,500 6,000	14-18	44-47	90-110	Si	dry crop	very good
Regent SiCL	2-35	mod. deep 26''	shale	slow	4-5	3,400 5,000	14-17	44-47	90-110	Cy	dry crop	good
Ringling channery L	8-95	shallow 15''	burned shale	rapid	1-2	3,400-5,000	14-17	45-47	90-105	TSi, TB	-	poor
Searing L	4-35	mod. deep 30''	burned shale	mod.	4-5	3,500 5,000	15-17	45-47	95-115	Si, Forest	dry crop	good
Shaak SiCL, CL	0-15	deep 60''+	alluvium, shale	slow	6-8	3,500 5,000	14-17	44-47	90-105	Si	dry&irr. crop	good
Shale outcrop	15-100	very shallow		impermeable						TB	wildlife	unsuitable
Spearman L	4-15	mod. deep 30''	burned shale	mod.		3,500 4,000	12-14	48-49	105-110	Si	dry crop	good
Talag C	0-8	deep 60''+	limy alluvium	very slow	6-8	3,000 3,700	13-14	48-50	110-125	Cy	-	fair

APPENDIX D-4 (cont.)

CHARACTERISTICS OF SOME COMMON SOILS, THEIR PRODUCTIVITY, AND THEIR VALUE AS TOPSOILING MATERIAL IN RECLAIMING STRIP-MINED LAND

Soil Series and Texture 1/	Slope Range (%)	Depth	Parent Material	Permeability	Water-holding capacity (inches)	Elevation (feet)	Annual Precipitation (inches)	Mean Annual Soil Temp(^{o}F)	Frostfree Growing Season (Days)	Range Site 2/	Use 3/	Rating as Topsoiling Material
Thedalund L	4-90	mod. deep 28''	siltstone	mod.	4-5	2,800 3,800	12-14	48-50	105-125	Si, TSi	-	poor
Thurlow SiCL	0-15	deep 60''+	limy alluvium	mod.	9-11	2,800 3,600	12-14	48-50	110-125	Cy	irr.&dry crop	good
Travessilla FSL	4-15	shallow 18''	limy sandstone	rapid	1-3	3,200 3,800	12-14	50-55	115-120	TB	-	unsuitable
Tullock LFS	8-15	mod. deep 40''	sandstone	rapid	3-4	3,200 3,600	13-14	49-50	110-120	Sa	-	fair
Vebar FSL	4-15	mod. deep 40''	sandstone	mod. rapid	4-6	3,400 4,400	14-16	46-47	100-115	Sy	dry crop	good
Wages L	0-8	deep 60''+	limy alluvium	mod.	8-10	3,000 3,600	13-14	47-49	105-115	Si	irr.&dry crop	excellent
Wayden SiCL	4-55	shallow20''	shale	slow	3-4	3,600 4,600	14-17	45-47	90-105	Cy, TCy	-	poor
Wibaux L	4-90	shallow10''	burned shale	mod. rapid	1-2	3,400 4,100	11-13	49-52	110-120	TB	-	poor

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1/ Soil series are not exactly synonymous with soil mapping units which may consist of one or more series. A series may be in one or more soil mapping units.

2/ For definitions of the range sites see Appendix E-2. For their correlation with the plant community types, see page 101 of the vegetation discussion. Range sites serve as one measure of soil productivity.

3/ Each soil is used also for grazing and to some extent as wildlife habitat. The permissible use of a soil is another measure of its productivity.

Sources: Soil Survey, Big Horn County Area (10); Soil and Range Resource Inventory. East of Little Bighorn River (9).

Appendix E-1 PRINCIPAL TYPES OF PLANT COMMUNITIES

The following types include most of the kinds of plant communities on the portions of the land having potential for strip mining for coal.

1 Cropland - This type and alfalfa fields are shown on the soil and range inventory by the land use symbol L. The principal crop is winter wheat. Smaller acreages are in barley, oats, and other crops. Some cropland is present in all the precipitation zones. A very large acreage of cropland occupies much of the level to rolling land at the top of the Wolf Mountains in an area of 20 to 24 inches of annual precipitation. The crop yields are excellent.

2 Alfalfa - Some alfalfa is grown in each precipitation zone as hay for livestock. It appears the 15- to 19-inch zone has the largest acreage of this crop. Some typical locations are along the east-trending valleys on the east side of the Wolf Mountains on nearly level to strongly sloping land. Some of the fields are naturally subirrigated or are irrigated by various structures.

3 Tame Grass - These fields are either on rangeland used for grazing or in fields, usually fenced, to be cut for hay. The grass crop is largely dependent on the amount of rainfall received. In the 10- to 14-inch precipitation zone the crop almost invariably is standard crested wheatgrass. In the 15- to 19-inch zone smooth brome is commonly

chosen, and Kentucky bluegrass comes in as an invader or may sometimes be included in the grass seed mixture. White or alsike clover is sometimes sown with the grass. In the 20- to 24-inch zone timothy smooth brome is commonly used. At least one large field of orchard grass exists. Other grasses also are probably used.

4 Abandoned Cropland and Goback Land - Occasional fields in the more arid areas have been left idle for a year or two without tillage. Such areas are quickly invaded by various weedy annuals and sometimes by weedy perennials or other aggressive plants. These are invader species and are indicated in the appendix plant list by the code Iv. If the land is left untilled indefinitely, the vegetation gradually returns, by successive stages, to one of the vegetation types described below. In most cases one of the grassland, or grassland and shrub types, will take over.

5 Mixed Short and Midgrasses - This type belongs in the 10- to 14-inch precipitation zone and is limited largely to the northern tract of the Peabody permit area. The vegetation consists of perennial short and midgrasses, including some of those in Appendix F, respectively J and K. Some of the most common species are blue grama, western (bluestem) wheatgrass, little bluestem, and prairie junegrass. Few shrubs are included and not many forbs except as invaders in the overgrazed areas.

6 Mixed Midgrasses and Short Grasses - This type is comparable to the previous type except midgrasses are more important than the short grasses, and the annual precipitation is 15 to 19 inches. There is a greater variety and a higher proportion of forbs and some shrubs, especially on the sandier sites. Some of the most common grasses include western wheatgrass, sideoats grama, little bluestem, needle-and-thread, and green needlegrass. Prairie sandreed is the dominant grass on the sandy range sites.

7 Mixed Midgrasses and Tall Grasses - This is the grassland type in the 20- to 24-inch precipitation zone. The midgrasses in this type include timothy, orchardgrass, Kentucky bluegrass, smooth brome, and some of the native perennial grasses and sedges coded K in Appendix F. A few of the tall grasses (coded L) may be present. There is a variety of forbs and sometimes some shrubs.

8 Sagebrush and Grass - This type is more common in the northern third of the area. It is mainly in the 10- to 14-inch precipitation zone but also in the 15- to 19-inch zone. Big (and probably black) sagebrush is on the loam, silt loam, and clay loam soils. Silver sagebrush is on the sandy loam, loam, and silt loam soils. These three sagebrush species are entirely or almost entirely absent in the 20- to 24-inch precipitation zone. Short and midgrasses are present in proportion to the annual precipitation. Other shrubs and some forbs can be expected in the 15- to 19-inch zone.

9 Grass and Shrubs - In this type are included area of grassland with scattered shrubs and sometimes an occasional tree. All of the precipitation zones appear to be represented. In the 15- to 19-inch zone the commonest shrubs in this and types 6 and 8 include western snowberry, skunkbush sumac, horizontal juniper and Arkansas rose, with also big, black, or silver sagebrush in type 8.

10 Shrubby Land - In this type the presence of large shrubs is what gives the landscape its character. This type may occupy large or moderately large areas of sloping subirrigated land and north-facing slopes and narrower bands in draws and along streams in the 20- to 25-inch precipitation zone. In the more arid zones this type is generally confined to vary narrow bands in some of the deep draws or next to streams.

A few cottonwood, aspen*, willow, green ash, and boxelder may be present. American elms are not generally abundant, the Crow reservation being at or near the western limit of this tree's natural range. The principal shrubs include fireberry hawthorn and Douglas hawthorn*, chokecherry, American plum, Saskatoon serviceberry, buffaloberry, Rockymountain maple, Woods rose, and common snowberry. The starred* species appear to be confined to the 20- to 24-inch precipitation zone in the Wolf Mountains. A wide variety of forbs, ferns, midgrasses, tall grasses, and large sedges make up the undergrowth.

The shrubland and the next community type have less value for grazing than they would if the woody vegetation were absent, but the value for wildlife cover and food is very high. Some of the areas are valuable for wild fruits. These areas add much to the scenic values, especially at flowering time and at the height of the fall leaf coloration.

11 Hardwood Tree Community Along Drainageways - This community occupies a band along the principal streams and drainageways. It tends to have the same species as in the shrubland community, but the tree species rather than the shrub species are what gives the character to the landscape.

12 Wet Land - This community is in areas of shallow water or at least has a very high water table. It includes many of the plants coded Z in Appendix F, such as common reed, American mannagrass, cattail, wetland sedges, redosier dogwood, willows, and cottonwoods.

13 Ponderosa Pine Forest Types - These types consist of pure stands of ponderosa pine sometimes with some hardwood trees such as aspen and with an understory including varying proportions and amounts of shrubs, forbs, and grasses. Four degrees of canopy density may be recognized:

a.	Open Forest	0 to 9% canopy density
b.	Partial Forest	10 to 39% canopy density

c. Dense Forest 40 to 69% canopy density

d. Closed Forest 70 to 100% canopy density

In the soil and range inventory (10) the areas of Open Forest were included in the adjacent range site, as the canopy density is not dense enough to affect the herbaceous understory. The individual areas of Closed Forest were not large enough to justify mapping separately from areas of Dense Forest.

These pine forest types are present mainly on north facing slopes and high portions of the Wolf Mountains. The annual precipitation is mostly 15 to 24 inches.

APPENDIX E-2

LEGEND FOR RANGE SITES

Range sites are kinds of range land that differ from each other in their ability to produce a significantly different kind or amount of original vegetation. Current vegetative cover is indicated by the Range Condition Class. Only natural grasslands can be classified as range sites.
A soil group name is combined with the precipitation belt to designate a specific range site; e.g. Sandy 10-14".
The following range sites are listed in presumed order of natural productivity in "Excellent" condition.

Range Site Descriptions:

WL - WET LAND: Marshy lands with subirrigation where seepage, ponding, etc. raises water table to above the surface during only a part of the growing season. Too wet for cultivated crops but too dry for common reed, cattails, or true aquatics.

Sb - SUBIRRIGATED: Lands with water table rarely above the surface during the growing season but subirrigated most of the growing season.

SS - SALINE SUBIRRIGATED: Subirrigated land where salt and/or alkali accumulations are apparent and halophytes occur over a major part of the area.

Ov - OVERFLOW: Areas regularly receiving more than normal soil moisture because of run-in from higher land, including stream overflow, run-in from higher slopes, and areas with water spreading systems.

SO - SALINE OVERFLOW: Areas regularly receiving more than normal soil moisture because of run-in, where salt and/or alkali accumulations are apparent and halophytes occur over a major part of the area.

Sa - SANDS: Deep, loose, fine sands and very fine sands on nearly level to rolling relief; excepting compact dark nearly level loamy fine sands and loamy very fine sands.

Sv - SAVANNAH: Uplands on which grass cover with isolated trees is normal (climax). Do not confound with savannah type of cover resulting from overgrazing of natural grassland or cutting of natural forest land. This site is common at margins of forest climates and in grassland climates where soil moisture relations especially favor tree growth.

Sy - SANDY: All normal coarse to fine sandy loams (not true sands) plus dark nearly level loamy fine sands, and loamy very fine sands; excepting relatively impervious cemented sands.

Si - SILTY: All normal very fine sandy loams, loams, silt loams, and silts.

Cy - CLAYEY: All normal relatively pervious sandy to silty clay loams and clays--normally granular.

TSy - THIN SANDY: Thin but deep sandy soils--not true sands--usually of hills with smooth surfaced slopes generally over 20% but also of lesser slopes where cementing occurs in upper layers on drying.

TSi - THIN SILTY: Thin but deep silty soils of hills with smooth surfaced slopes generally over 15%.

TCy - THIN CLAYEY: Thin but deep clayey soils of hills with smooth surfaced slopes generally over 15%.

SwC - SHALLOW CLAY: Shallow normally granular clays of hills (10-20") often underlain by angular raw shale fragments.

SwG - SHALLOW TO GRAVEL: Shallow soils (10-20") resting on clean gravelly or cobbly materials.

SwL - SHALLOW LIMY: Shallow limy soils (10-20") underlain by rock virtually impenetrable by plant roots.

SwN - SHALLOW NONLIMY: Shallow neutral to acid soils (10-20") underlain by rock virtually impenetrable by roots.

Ps - PANSPOTS: Areas where hard clays or other impervious materials lie close to or at the surface in shallow depressions which occupy 20 to 50% of the area.

DC - DENSE CLAY: Relatively impervious deep but dispersed clays--may be orverlain by thin but ineffectual layers of other materials. The dispersed layer is very hard to extremely hard when dry and very sticky when wet.

TB - THIN BREAKS: Mixed soils of various depths derived from different parent materials that outcrop at different levels forming irregular slopes of from 20 to 65 percent. Trees may occur locally above outcrops.

Gr - GRAVEL: Uplands where rock fragments of gravel or small stone size compose most of the soil with coarse materials greatly reducing moisture retention with apparent effects on both amount and kind of native vegetation.

VS - VERY SHALLOW: Areas where few roots can penetrate deeper than 10". Outcropping of gravel or bedrock is characteristic. Joints in bedrock may develop deep soil pockets usually marked by tall grasses, shrubs, or stunted trees.

SU - SALINE UPLAND: Uplands of ordinary depth where salt and/or alkali accumulations are apparent and halophytes occur over a major part of the area.

Sh - SHALE: Readily puddled uplands where some unweathered angular raw shale fragments are exposed at the surface and little, if any, soil profile development is evident.

Bl - BADLANDS: Nearly barren lands broken by drainages dry most of the year, with intermingled grazable areas too small or too narrow to justify mapping separately.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

APPENDIX F PLANTS FOUND IN EAST END OF CROW RESERVATION

Explanation of the notations following the standardized plant name (Ecological and usefulness code)

A	Annual or winter annual	
B	Biennial	
C	Perennial	
D	Species that generally behaves as a decreaser under grazing pressure (13)	
E	Exotic or introduced species	
F	Usable source of human food for such parts as edible seeds or fruits, edible roots or tubers, pot herbs, salad ingredients, syrups, teas, or flavors (8), (14)	
Hf	Indicator plant for forest habitat types of central and eastern Montana (11)	
Iv	Plant that generally behaves as an invader under grazing pressure (13)	
J	Short grass	
K	Midgrass	
L	Tall grass	
M	Species that is a potential source of commercial drugs (7), (8), (14)	
N	Species that is native to the region	
O	Species with attractive flowers or fruits or other special ornamental value. In addition many of the shrub and tree species not so marked have value in landscape gardening.	
P	Species that may be poisonous to humans or livestock or pets under certain conditions (7)	
Q	Species growing as a bunchgrass, single specimen or in close clump (12), (13)	
R	Species spreading by rhizomes, stolons, suckers, etc., to form a sod, mat, or thicket (12), (13)	
S	Species moderately tolerant to salt or alkali conditions	This environment is called "halic".
$	Species very tolerant to salt or alkali conditions	The plants are called "halophytes".
T	Species useful for timber	
*	Species with awns, burs, or other parts mechanically injurious to livestock	
U	Species that may be undesirable--weed (7) (See also P and *)	
V	Species with a vine or creeping growth habit (13)	
W	Species useful for wildlife (7)	
X	Species adapted to a "xeric" or dry environment or soil. Plants structurally adapted to a limited water supply are called "xerophytes".	
Y	Species growing on or needing an environment or soil having a balanced or moderate moisture supply. Such plants are called "mesophytes". The environment or soil is classed as "mesic".	
Z	Species adapted to a "hydric" or wet or very moist environment or soil. Plants adapted to waterlogged or submerged sites are called "hydrophytes".	
@	Cool-season plant	
#	Warm-season plant (12), (13)	

If the symbols (F), (M), (O), (P), (U) or (W) are enclosed in parentheses it means that the named genus includes species having the indicated characteristic.

Species are listed in the following groups: Cryptogams, Grasses, Grasslike plants, Leguminous forbs, Other forbs, Shrubs, and Trees.

The Latin name is one that is in common use in recent years. Latin names in parentheses are synonyms under which the plant is sometimes listed. The name used in Standardized Plant Names (7) is included if there is one.

The standardized plant name is the one used in the 1942 edition of Standardized Plant Names (7) if that book lists one. Names in parenthese following the standardized plant name are other common names, which in some cases are more common than the standardized name.

For considerable information on the adaptability of a number of native and introduced species, particularly those usable for revegetation purposes consult references (12) and (13). The latter reference contains more specific information on ecological factors and identification features than can be shown in our coding system.

A few of the species on the plant list are not included in references (1), (2), (5) or (6) as belonging in the flora of Montana. It may be that in these instances some of the source material for the list may have misidentified these species or else that the species are not previously known for Montana.

LATIN (scientific) NAME	STANDARDIZED PLANT NAME (Other common names in parenthese)	ECOLOGICAL AND USEFULNESS CODE
Cryptogams (primitive nonflowering plants)		
Azotobacter, Clostridium, Nitrobacter, mycorhizae, etc.	miscellaneous soil microorganisms	
Claviceps purpurea	ergot	M P
------	miscellaneous unidentified fungi, mushrooms, algae, lichens, mosses, and liverworts	(F) (P) (W)
Equisetum spp.	horsetail species, including scouring rushes	(F) Hf (P) (W)
Pteridium aquilinum	bracken (brake)	C F MN PR Y
Selaginella densa /not in SPN/	small selaginella (small clubmoss)	C N X
Grasses		
Agropyron spp.	wheatgrass species	
" albicans	Montana wheatgrass	C K N R Y @
" cristatum	fairway crested wheatgrass	C E K Q X @
" dasystachyum	thickspike wheatgrass	CD K N RS Y @
" desertorum /not in SPN/	desert (standard crested) wheatgrass	C E K QS X @
" elongatum	tall wheatgrass	C E K Q Y @
" smithi	bluestem (western) wheatgrass (bluejoint)	C K N R$ WY @

Grasses (continued)

Agropyron spicatum	bearded bluebunch wheatgrass	CD	HfK	N	Q		WY	@
" subsecundum	bearded wheatgrass	CD	K	N	Q		Y	@
" trachycaulum (pauciflorum)	slender wheatgrass	CD	K	N	Q$		WY	@
Agrostis alba	redtop	CE	IvK		R		WY	@
Andropogon spp.	bluestem species							(W)
" halli	sand bluestem (turkeyfoot)	CD	L	N	R		Y	#
" gerardi (furcatus)	big bluestem (bluejoint turkeyfoot)	CD	L	N	R		WY	#
" scoparius (Schizachyrium scoparium)	little bluestem (prairie beardgrass)	CD	K	N	Q		WY	#
Aristida fendleriana	Fendler (small) threeawn	C	Iv	N	Q	*	WX	@
" longiseta	red threeawn	C	IvJ	N	Q	*U	WX	@
Beckmannia syzigachne	American sloughgrass	A F	IvK	N	Q		WZ	#
Bouteloua curtipendula	sideoats grama	CD	K	N	R		Y	#
" gracilis	blue grama	C	J	N	QRS		WX	#
Bromus spp.	brome species (bromegrass)							(W)
" inermis	smooth brome	CE	K		R$		Y	@
" japonicus	Japanese brome (chess) (wintergrass)	AE	IvK		Q	U	X	@
" tectorum	cheatgrass brome (downy chess)	AE	IvK		Q	*U	WX	@
Calamagrostis montanensis	plains reedgrass	CD	J	N	R		Y	@
Calamovilfa longifolia	prairie sandreed (sandgrass)	CD	L	N	R		Y	#
Cenchrus pauciflorus (longispinus)	mat sandbur (grassbur)	A F	IvJ	N	Q	*U	WX	#
Dactylis glomerata	orchardgrass (cocksfoot)	CE	K		Q S		WY	@
Danthonia intermedia	timber danthonia (oatgrass)	C		N	Q		Z	
" parryi	Parry danthonia (oatgrass)	CD		N			Y	
Deschampsia caespitosa	tufted hairgrass	CD	K	N	Q		WZ	@
Distichlis stricta	inland saltgrass (alkaligrass)	C	J	N	R$		W	#
Echinochloa crusgalli	barnyardgrass	AEF	IvL		Q	U	WY	#
Elymus spp.	wildrye species							(W)
" canadensis	Canada wildrye	CD	L	N	Q $		Y	@
" cinereus (condensatus pubescens)	inland giant wildrye (basin wildrye)	CDF	L	N	Q		Y	@
Eragrostis cilianensis	stinkgrass (stinking lovegrass)	AE	IvJ		OPQ	U	WY	#

Grasses (continued)

Festuca idahoensis	Idaho fescue	C	HfJ	N	Q		Y	@
" octoflora	sixweeks fescue	A	IvJ	N	Q	U	WX	@
" ovina	sheep fescue	CDE	K	N	Q		W	@
Glyceria spp.	mannagrass species	(F)						(W)
Hesperochloa (Festuca) kingi	spikefescue	CD		N	R		X	
Hordeum jubatum	foxtail (squirreltail) barley	C	IvK	N	QS	*U	W	@
Koeleria cristata	prairie junegrass	CD	K	N	Q		WY	@
Muhlenbergia asperifolia	alkali muhly (scratchgrass)	C	J	N	RS		WZ	#
" cuspidata	stonyhills (plains, Utah) muhly	CD	J	N	Q		Y	#
" racemosa	green (marsh) muhly	CD	K	N	R		Z	#
" richardsonis (squarrosa)	mat muhly	C	J	N	RS		Y	#
Oryzopsis hymenoides	Indian ricegrass (Indian millet, sandrice, silkygrass, sandgrass)	CDF	K	N	Q		WX	@
Panicum capillare	common witchgrass (ticklegrass, tumblegrass)	A	IvK	N	Q	U	WY	#
" virgatum	switchgrass	CD	L	N	RS	U	WZ	#
Phleum pratense	timothy (herdsgrass)	CE	K		Q		WY	@
Phragmites communis	common reed	C F	L	NO	R		WZ	#
Poa spp.	bluegrass species							(W)
" bulbosa	bulbous bluegrass /has bulblets/	CE	J		Q		Y	
" canbyi	Canby bluegrass	CD	K	N	Q		WX	@
" juncifolia	alkali bluegrass	CD		N	S		WY	
" pratensis	Kentucky bluegrass	CE	IvK		R		WY	@
" secunda	Sandberg (little) (western) bluegrass	C	J	N	Q		WY	@
Puccinellia airoides (nuttalliana)	Nuttall alkaligrass	CD	J	N	Q$		W	@
Schedonnardus paniculatus	tumblegrass	C	IvJ	N	Q	U	Y	#
Sitanion hystrix	bottlebrush squirreltail (bristlegrass, bushtail, foxtail)	C	J	N	Q	*	WX	#
Sorghastrum nutans	yellow Indiangrass	CD	K	N	R		Y	#
Spartina pectinata	prairie cordgrass (sloughgrass, tall marshgrass)	CD	L	N	RS		WZ	#
Sporobolus airoides	alkali sacaton (bigplume bunchgrass, firetop saltgrass, hairy dropseed)	CDF	K	N	Q$		W	#

Grasses (continued)					
Stipa spp.	needlegrass species		(M)		(W)
" columbiana	subalpine (Columbia) needlegrass	CD	N	X	
" comata	needleand thread (speargrass)	C	K N Q	*U WX	@
" richardsoni	Richardson needlegrass	C	N	Y	
" viridula	green needlegrass (feather bunchgrass)	CD	K N Q	WY	@
Trisetum spicatum	spike trisetum	CD	N Q	WY	
Triticum aestivum	wheat	AEF	K Q	WY	#
Grasslike plants					
Carex spp.	sedge species of dry sites			X	(W)
" spp.	sedge species of wet and moist sites			YZ	(W)
" eleocharis (stenophylla)	needleleaf sedge	C	IvJ N R	WYZ	@
" filifolia	threadleaf sedge (niggerwool, blackroot)	C	J N Q	X	@
" geyeri	elk sedge	C	HfK N R	Y	
Eleocharis palustris	common spikesedge (big spikerush)	CD	K N R	W Z	@
Juncus spp.	rush species			(U)	(W)
" effusus	common (bog) rush	C	N Q	W	@
Typha latifolia	common cattail	C F	LMNO R	W Z	
Leguminous forbs					
Astragalus spp.	milkvetch species /These are nonpoisonous/		(O)		(W)
" "	loco (locoweed) species /These cause locoism/		(M) (O)P		
" "	poisonvetch species /These are selenium accumulators/		(O)P		
" bisulcatus	twogrooved loco (poisonvetch) /a selenium indicator/	C	N OPQ	X	
" caespitosus	/no SPN/ blue tufted milkvetch	C	N O Q	X	
" crassicarpus (caryocarpus)	groundplum milkvetch, (buffalobean)	CD	N O Q	Y	
" flexuosus	flexile (slender) milkvetch	C	N O Q	VX	
" pectinatus	narrowleaf poisonvetch	C	N OPQ	X	

Leguminous forbs (continued)

Astragalus triphyllus (gilviflorus)	/no SPN/ white tufted milkvetch	C	NO Q	X	
Dalea enneandra	/no SPN/ bigtop (plume) dalea	CD	NO Q		
Glycyrrhiza lepidota	American licorice	C F	MN R	*U WY	
Lupinus argenteus	silvery lupine	C	NOPQ	Y	
Medicago lupulina	black medic	ABEFIv		U WY	
" sativa	alfalfa (lucerne)	C E	OPQ$	WY	
Melilotus spp.	sweetclover species				(W)
" alba	white sweetclover	BE Iv	PQS	WY	
" officinalis	yellow sweetclover	BE Iv	M OPQS	WY	
Onobrychis viciaefolia	common sainfoin	C E	O $	Y	
Oxytropis lamberti	Lambert crazyweed (purple loco)	C	MNOPQ	Y	
Petalostemon spp.	prairieclover species		(O)		(W)
" candidus	white prairieclover	CD F	NO Q	Y	#
" purpureus	purple prairieclover	CD F	MNO R	X	#
Psoralea spp.	scurfpea		(O)		(W)
" argophylla	silverleaf scurfpea	C	NOPQ	WY	
" esculenta	common breadroot scurfpea, (tipsin, Indian, or prairie turnip)	C F	NOPQ	Y	
" lanceolata	lemon scurfpea	C	NO R	Y	
" tenuiflora	slimflower scurfpea, (wildalfalfa)	C	NO Q	Y	#
Thermopsis rhombifolia	plains thermopsis (goldenpea)	C	MNOPR	Y	
Trifolium spp.	clover species	(F)	(M) (O)	(U)	(W)
" repens	white clover	C EFIv	OPR	WY	
Vicia spp.	vetch species	(F)	(O)	V	(W)
" americana	American (purple) vetch	CD F	NO R	V Y	

Other forbs (including some vines and fibrous or half-woody species).

Achillea lanulosa /sometimes included in A. millefolium/	western yarrow (milfoil)	C FIv	MNO R	U WX	#
Actaea rubra /includes A. arguta/	red (&western) baneberry	C Hf	NOPQ	Y	
Actinea acaulis	stemless actinea, (buttemarigold)	C	NO Q	X	
Agoseris cuspidata (See Microseris cuspidata)					
Allionia (Mirabilis) myctaginea	prairie allionia (wildfouroclock)	C	N Q	Y	
Allium spp.	onion and garlic species	(F)	(M) (O)		(W)

Other forbs (including some vines and fibrous or half-woody species). (continued)

Allium stellatum	prairie (pink) onion	C	F	NO Q		Y	
Amaranthus blitoides (graecizans)	prostrate (creeping, tumbleweed) amaranth (pigweed)	A		N	U	WY	
" retroflexus	redroot amaranth (rough pigweed)	A	EFIv	N PQ	U	Y	
Ambrosia psilostachya (coronopifolia)	western (perennial) ragweed	C	F	N PR	U	WY	#
" trifida	giant (tall) ragweed, (kinghead)	A		N PQ	U	WY	
Anemone cylindrica	candle anemone, (cottonweed)	C		N		Y	
" patens	spreading pasqueflower, (windflower, mayflower, wild "crocus")	C		MNOPQ		WY	
Anogra (See Oenothera)							
Antennaria spp.	pussytoes (catsfoot)	(F)		(O) (R)			(W)
Aplopappus (Haplopappus, Sideranthus)	goldenweed species		(M)	(O) (P)			
" spinulosus	ironplant (cutleaf, spiny) goldenweed (burrowweed, sideranthus)	C		NOPQ		X	
/sometimes classed as a shrub/							
Apocynum androsaemifolium	spreading dogbane	C		MNOPQR		Y	
/sometimes classed as a shrub/							
Aquilegia spp.	columbine species			(O)			(W)
Arctium lappa	great burdock		BEFIv	M	*U	WY	
Argemone intermedia (polyanthemos)	intermediate pricklepoppy /no SPN/	A		NOPQ	*U	WX	
Arnica spp.	arnica species		(M)	(O)			
" cordifolia	heartleaf arnica	C	Hf	NO R		Y	
Artemisia spp. (herbaceous kinds)	sagebrush (sagewort) species	(F)	(M)				
" dracunculus (glauca, dracunculoides)	tarragon (green, falsetarragon) sagebrush	C		MN Q		X	
Artemisia frigida	fringed (pasture) sagebrush	C	F	MNO Q	U	WX	
" longifolia	longleaf sagebrush	C		N QS			
" ludoviciana (gnaphalodes)	Louisiana (cudweed) sagebrush	C		MN R	U	X	
" michauxiana (discolor)	Michaux (sweet) sagebrush	C		N Q		Y	
/Some of these Artemisia species tend to be half-woody shrubs and are sometimes included with shrubs/							
Asclepias spp.	milkweed species	(F)	(M)	(O) (P)	(U)	(W)	
" pumila	plains (low) milkweed	C		N P	U	X	
" speciosa	showy milkweed	C		NOPR	U	X	
" syriaca	common milkweed	C		MN PQ	U	WX	
" verticillata	whorled milkweed	C		MN PR	U	X	

Other forbs (including some vines and fibrous or half-woody species). (continued)

Asparagus officinalis	garden asparagus	C EFIv M O R WY
Aster spp.	aster species	(F) (O) (P)
" ericoides (multiflorus)	heath (many-flowered) aster	C NO R U X #
Balsamorhiza sagittata	arrowleaf balsamroot	C FHf MNO Q WY
Bidens spp.	beggarticks species	(A) (F) (Iv) *(U) (W)
Brassica spp.	mustard species	(F) (M) (O) (U) (W)
Calochortus nuttalli	segolily mariposa	C F NO Q X
Campanula petiolata	American harebell	C F NO Y
/sometimes included in C. rotundifolia		
Capsella bursa-pastoris	shepherdspurse	A EF M U WY
Castilleja spp.	paintedcup species (Indianpaintbrush)	(F) (O) (W)
/Many species are partial root parasites. Many species are selenium accumulators/		
Castilleja sessiliflora /not in SPN/	downy paintedcup	C NO X
Cerastium arvense	starry cerastium (prairie or field chickweed)	C NO UVWY
Chamaenerion (See Epilobium)		
Chenopodium spp.	goosefoot species	(F) (M) (U) (W)
" album	lambsquarters goosefoot	A EFIv Q U WY
Chrysopsis (Heterotheca) villosa	hairy goldaster	C NO Q U X
Cicuta douglasi	Douglas waterhemlock	C NOPQ Z
/May be called C. maculata or C. occidentalis on some plant lists/		
Cirsium spp.	thistle species	(F) *(U) (W)
" arvense	Canada thistle	C EFIv R *U WY
" undulatum	wavyleaf (prairie) thistle	BC FIv NO Q *U X
Cleome serrulata	bee spiderflower, (beeplant, stinkflower)	A FIv O Q U WY
Cogswellia (See Lomatium)		
Comandra umbellata (pallida) /a partial root parasite/	common comandra (bastardtoadflax)	C F N R X
Conringia orientalis	treacle hairsear (hairsear mustard)	A E Iv Q U Y

Other forbs (including some vines and fibrous or half-woody species). (continued)

Convolvulus arvensis	European glorybind (field bindweed, creepingjenny)	C E		O R	UV	Y	
Corydalis aurea	golden corydalis	AB	Iv	NOP	UV	Y	
Cryptantha bradburiana (sheldoni) (Oreocarya glomerata)	Sheldon cryptantha, (white forget-menot, buttecandle, minerscandle)	BC		NO Q		X	
Cynoglossum officinale	common houndstongue	B E		M PQ	*U	Y	
Delphinium spp.	larkspur species			(O) (P)			
" bicolor	little (low) larkspur	C		NOPQ		Y	
Dodecatheon spp.	shootingstar species			(O)			
" meadia	common shootingstar	C		NO Q		Z	
Echinacea pallida	pale echinacea (purpleconeflower)	CD		MNO Q		X	#
/sometimes confused with E. angustifolia, a more eastern species/							
Epilobium (Chamaenerion) spp.	willowweed species						(W)
" angustifolium	fireweed	C	FIv	MNO R		Y	
" paniculatum	autumn willowweed (panicled willowherb)	A		NO		X	
Erigeron spp.	fleabane species			(O)			(W)
" canadensis (Conyza c.)	horseweed (Canada) fleabane, (marestail)	A	Iv	MN PQ	U	Y	
" divergens	spreading fleabane	A	Iv	NO Q		X	
" strigosus (ramosus)	/no SPN/ daisy fleabane	AB	Iv	No Q	U	X	
Eriogonum spp.	eriogonum (buckweat) species	(F)	(M)	(O)			(W)
Eriophyllum lanatum	woolly eriophyllum			N		Y	
Erysimum (Cheirinia) asperum	plains erysimum, (western wall-flower)	BC		NO Q	U	Y	
Euphorbia spp.	euphorbia species						(W)
" esula	leafy euphorbia (spurge)	C E	Iv	PR	U	Y	
" marginata	snow-on-the-mountain euphorbia	A E		OPQ		X	#
" serpyllifolia	thymeleaf (prostrate) euphorbia (spurge)	A	FIv	PQ	V	Y	
Eurotia lanata /a half-woody shrub/	common winterfat, (whitesage, sweetsage)	C		N QS	W	X	
Fragaria spp.	strawberry species	(F)					(W)
Fritillaria pudica	yellow fritillary	C	F	NO Q		Y	
Gaillardia aristata	common perennial gaillardia (blanketflower)	C		NO Q		Y	

Other forbs (including some vines and fibrous or half-woody species). (continued)

Galium aparine	catchweed bedstraw	A	F	MN	Q	U	WY	
" boreale	northern bedstraw	C		NO	Q	U	WY	
Gaura coccinea	scarlet gaura (butterflyweed)	C		NO	R		WX	
Geranium viscosissimum	sticky geranium	C		NO	Q		WY	
Geum triflorum (Sieversia triflora) /not in SPN/	prairie smoke, (torchflower, or oldmanswhiskers, purple awens)	C	F	NO	Q		Y	
Grindelia squarrosa /a selenium accumulator/	curlycup gumweed (tarweed, resinweed)	B	FIv	MN	Q	U	WX	#
Gutierrezia sarothrae /a half-woody shrub, a selenium absorber/	broom snakeweed, (broomweed, matchweed, turpentineweed, yellowcup)	C	Iv	NOPQ		U	X	
Helianthus annuus	common sunflower	A	FIv	MNO	Q	U	WY	
" maximiliani	Maximilian sunflower	CD	F	NO	R	U	WY	#
Heracleum lanatum	common cowparsnip	BC	F	MNO	Q		Y	
Hesperis matronalis	dames (sweet) rocket	B	Iv	O	Q		Y	
Heterotheca (See Chrysopsis)								
Heuchera spp.	alumroot species	(F)	(M)					
Humulus americanus /sometimes included in H. lupulus/	/no SPN/ American hop	C	F	N	R	V	Y	
Hymenoxys (See Actinea)								
Iva xanthifolia	rag sumpweed (burweed marshelder)	A	Iv	N	PQ	U	WY	
Kochia scoparia	belvedere summercypress (fireweed, burningbush)	A	EFIv	O	Q	U	Y	
Lactuca pulchella	chicory (blue) lettuce	CD	F	NO	R	U	WY	
" serriola (scariola)	prickly (China) lettuce	A	E Iv		Q	*U	Y	
Lappula redowski (occidentalis)	/no SPN/ beggarticks, (western or low stickseed)	A	Iv	N	Q	*U	WX	
Leontodon taraxacum (See Taraxacum officinale)								
Lesquerella argentea	silver bladderpod	C		NO				
Leucocrinum montanum	common (mountain) starlily (mountainlily, sandlily, sagelily)	C	F	NO	QR		WX	
Lewisia rediviva	bitterroot lewisia	C	F	MNO	Q		WY	
Liatris ligulistylis	rockymountain gayfeather	CD		MNO	Q		Y	
" punctata	dotted gayfeather (blazingstar)	CD	F	NO	Q		X	#
" scariosa	tall gayfeather (blazingstar)	CD		MNO	Q		Y	

Other forbs (including some vines and fibrous or half-woody species). (continued)

Linaria vulgaris	butterandeggs toadflax (stinkweed)	C E Iv M O R U Y
Linum lewisi /perenne on some lists/	Lewis (prairie) flax	CD F MNOPQ Y
" rigidum	stiffstem flax	A Iv NOPQ Y
Lithospermum spp.	gromwell (stoneseed) species	(M) (U) (W)
" incisum (angustifolium)	narrowleaf (cleft) gromwell (puccoon)	CD F NO Q WX
Lomatium (Cogswellia) spp.	lomatium (wildparsley) species /includes biscuitroots/	(F) (W)
Lygodesmia juncea	rush skeletonplant (skeletonweed), (prairiepink)	C F MN PR U X
Malva rotundifolia	running mallow (cheeses)	ABE Q UVWY
Malvastrum coccineum (See Sphaeralcea coccinea)		
Mamillaria (Coryphantha, Neomamillaria) spp.	coryphantha (ballcactus, nipplecactus, pincushion)	(O) *
/Mamillaria species are sometimes listed with shrub species/		
Mamillaria missouriensis	Missouri coryphantha (yellow-flowered pincushion)	C NO Q * X
" vivipara	/no SPN/ red-flowered pincushion	C NO Q * X
Mentha spp.	mint species	(F) (M) (W)
Mentzelia decapetala	tenpetal mentzelia (eveningstar, "chalklily") /a selenium accumulator/	BC MNOPQ X
Mertensia spp.	bluebells (lungwort, chimingbells) species	(O)
" lanceolata	lanceleaf bluebells	C NO Q X
Microseris (Agoseris) cuspidata	wavyleaf agoseris (prairiedandelion, falsedandelion)	C NO X
Mirabilis (See Allionia)		
Monarda spp.	beebalm (horsemint) species	(F) (M) (O) (W)
" fistulosa (menthaefolia)	wildbergamot (mintleaf) beebalm	CD F NO R Y
Musineon divaricatum /not in SPN/	wildparsley	C NO Q X
Oenothera (Anogra) spp.	eveningprimrose and sundrop species	(W)
" caespitosa	tufted eveningprimrose, (butte primrose, "gumbolily")	C F NO Q Y

Other forbs (including some vines and fibrous or half-woody species). (continued)

Oenothera serrulata	/no SPN/ halfshrub sundrop, tooth-leaved eveningprimrose /a half-woody shrub/	CD		NO	Q	X	#
Onosmodium occidentale (molle)	western marbleseed (falsegromwell)	C		N	Q	WY	
Opuntia spp.	pricklypear species	C	(F)	(M)O		*(U)	
/Opuntia species are sometimes classed with shrubs/							
Opuntia fragilis	brittle pricklypear	C		NO	QS	*U X	
" polyacantha	plains pricklypear	C	F	MNO	Q	*U WX	
Oreocarya glomerata (See Cryptantha bradburiana)							
Orobanche spp.	broomrape species /parasitic plants/		(F)	(O)			(W)
Osmorhiza occidentalis	sweetanise (sweetcicely) (western sweetroot)	C	F	NO	Q	Y	
Penstemon spp.	penstemon (beardtongue) species			(M) (O)			(W)
" angustifolius	narrowleaf penstemon	CD		MNO	Q	Y	
" nitidus	waxleaf penstemon	CD		NO	Q	Y	
Phacelia spp.	phacelia species			(O)			
Phlox spp.	phlox species			(O)			(W)
" hoodi (canescens)	Hoods (moss, hoary) phlox	C		NO	Q	WX	
Physalis longifolia /not in SPN/	long-leaved groundcherry	C	F	N		Y	
Physaria brassicoides /not in SPN/	double bladderpod	C		NO	Q	X	
Plantago purshi	wooly indianwheat (prairie plantain)	A	Iv	N	Q	U WX	#
" spinulosa	/no SPN/ bracted (spiny) indianwheat, (spindle plantain)	AC	Iv	N	Q	X	#
Polygonatum commutatum	great solomonseal	C		NO	R		
Polygonum spp.	knotweed species		(F)				(W)
" aviculare	prostrate knotweed, (doorweed, goosegrass)	A	Iv	N	Q	UVW	
" (Bistorta) bistortoides	American bistort (knotweed)	C	F	NO		Z	
" sawatchense	sawatch knotweed	A	Iv	N		Y	
Potentilla spp.	cinquefoil species		(F)	(M) (O)			(W)
" anserina	silverweed cinquefoil	C	F	MNO	RS	UVWYZ	
" concinna	elegant cinquefoil	C		NO	Q	X	
Ranunculus spp.	buttercup species		(F)	(M) (O)	(P)	(U)	(W)

Other forbs (including some vines and fibrous or half-woody species). (continued)

Ratibida (Lapachys) columnaris (columnifera)	upright prairieconeflower	CD F NO Q X
Rumex spp.	dock (sorrel) species	(F) (M) (O) (P) (U) (W)
" occidentalis	western dock	C N Q WZ
Salsola kali	common russianthistle (saltwort)	A EFIv Q *U WX
Sedum stenapetalum	wormleaf (yellow) stonecrop	C NO X
Senecio spp.	groundsel (ragwort) species	(M) (O) (P) (W)
" aureus	golden groundsel (ragwort)	CD M OPR U WZ
Sieversia triflora (See Geum triflorum)		
Sisymbrium altissimum	tumblemustard	A EFIv Q U WY
Sisyrinchium angustifolium	common blue-eyedgrass	C NO Q Y
Solidago spp.	goldenrod species	(M) (O) (U) (W)
" altissima	tall goldenrod	C NO Q Y
" missouriensis	Missouri (early) goldenrod	C F MNO R Y #
" mollis /not in SPN/	soft (velvety) goldenrod	CD NO R X
" rigida	stiff goldenrod	C NO QR Y #
Sphaeralcea coccinea (Malvastrum coccineum)	scarlet globemallow (red mallow)	C F MNO Q WX
Stanleya spp.	princesplume species /selenium indicators and accumulators/	
" pinnata	desert princesplume /half-woody shrub/	C F MNOPQ X
Streptopus amplexifolius	claspleaf twistedstalk	C FHf NO R Y
Tanacetum vulgare	common tansy	C E M O U Y
Taraxacum officinale	common dandelion	C EFIv M Q U WY
Thlaspi arvense	field pennycress (fanweed, frenchweed)	A EFIv Q U WY
Tradescantia occidentalis	prairie spiderwort	CD F NO Q Y
Tragopogon spp.	salsify (goatsbeard, oysterplant) species	(F) (M) (O) (W)
" dubius /not in SPN/	large (common) salsify	BEFIv O Q U Y
" pratensis	meadow salsify	BEFIv O Q U Y
Tribulus terrestris	puncturevine	A E Iv Q *UVWX
Urtica dioica	bigsting (stinging) nettle	C F MN PR U Y
Viola spp.	violet species	(F) (O)
" nuttalli	Nuttall (yellow prairie) violet	CD NO QR Y

Other forbs (including some vines and fibrous or half-woody species). (continued)

Xanthium spp.	cocklebur species (sheepbur, clotbur)	(M) (P) *(U) (W)#
" strumarium	/no SPN/ cocklebur	A PQ *U Y #
Yucca glauca	small soapweed (yucca), (spanish-bayonet)	C NO Q *U X
Zigadenus (Zygadenus) spp.	deathcamas species	(M) (O) (P) (W)

Shrubs and woody vines

Amelanchier alnifolia	saskatoon (western) serviceberry, (juneberry)	C F NO R WY
Amorpha canescens	leadplant amorpha, (prairie shoestring)	CD F NO Q U WX #
Arctostaphylos uva-ursi	bearberry (kinnikinnick)	C FHf MNO VWY
Artemisia cana	silver (gray, hoary, white) sagebrush	C N Q W
" nova (arbuscula v. nova)	black sagebrush	C N Q WX
" tridentata	big sagebrush	C F MN Q U WX
/For herbaceous and half-woody species of Artemisia see the forb list./		
Atriplex confertifolia	shadscale (spiny) saltbush	C F N QS X
" nuttalli (gardneri)	Nuttall (Gardner) saltbush, (saltsage)	C N PQS X
/Additional species of Atriplex are in the forb list./		
Berberis repens (See Mahonia)		
Betula occidentalis (fontinalis)	water (river, black) birch	C N Q WY
/This species may sometimes be classed as a small tree. For other birch species see the tree list./		
Ceanothus spp.	ceanothus species	(F) (M) (W)
Cercocarpus montanus	true mountainmahogany	C N W
Chrysothamnus spp.	rabbitbrush species	(O) (W)
" nauseosus (graveolens)	rubber (greenplume) rabbitbrush	C FIv MNO Q X
" viscidiflorus (lanceolatus)	Douglas (green, lanceleaf) rabbitbrush	C Iv NO Q X
Clematis ligusticifolia	western virginsbower (white clematis)	C MNO V Y
Cornus stolonifera	redosier (red) dogwood	C F NO WYZ

Shrubs and woody vines (continued)

Crataegus spp.	hawthorn (thornapple) species	(F)		(O)		(W)	
" chrysocarpa (succulenta, rotundifolia)	fireberry (fleshy, roundleaved) hawthorn	C	F	NO R		WY	
Crataegus columbiana /not in SPN/	Columbia hawthorn	C	F	NO R		WY	
" douglasi (rivularis)	Douglas (black, river) hawthorn	C	F	NO		WY	
Eurotia lanata	common winterfat, (whitesage, sweetsage)	C		N QS		WX	
Grossularia (See Ribes)							
Gutierrezia sarothrae	broom snakeweed, (broomweed, matchweed, turpentineweed, yellowcup) /a selemium accumulator/	C	Iv	N PQ	U	X	
Juniperus communis	common juniper	C	FHf	MN Q		W	
" horizontalis	creeping juniper	C	FHf	N		VWX	
Mahonia (Berberis) repens	creeping mahonia (hollygrape, "oregongrape")	C		MNOPR		VWY	
Oenothera serrulata	/no SPN/ halfshrub sundrop, (toothleaved or shrubby eveningprimrose)	CD		NO Q		X	#
Potentilla (Dasiphora) fruticosa	bush (shrubby) cinquefoil	C		NO QS		WX	
Prunus americana	American plum	C	F	NOPRS		WXY	
" besseyi	Bessey cherry (western sand cherry)	C	F	NOP		WX	
" virginiana	common chokecherry (may include the next)	C	FHf	NOPRS		WY	
" virginiana v. demissa	western chokecherry	C	FHf	MNOPRS		WY	
Rhus glabra	smooth sumac	C	F	MNO R	U	WY	
" radicans (See Toxicodendron r.)							
" trilobata	skunkbush (fragrant, ill-scented, lemonade) sumac, (skunkbrush, squawbrush)	C	F	MNO QS		WX	
Ribes (Chrysobotrya) spp.	clove currant species	(F)		(O)		(W)	
" (Grossularia) spp.	gooseberry species /These have thorny stems./	(F)		(O)		(W)	
" spp.	currant species	(F)		(O)		(W)	

Shrubs and woody vines (continued)

Ribes americanum	American black currant	C	F	N	Q		Y
" odoratum /sometimes included in R. aureum/	clove (golden) currant	C	F	NO	Q		WY
Ribes setosum	redshoot gooseberry	C	F	N			WY
Rosa spp.	rose species	(F)	(M)	(O)			(W)
" arkansana	Arkansas (prairie) rose	C	F	NO	R	U	WXY
" woodsi	Woods rose	C	F	NO	R		WY
Rubus spp.	raspberry, dewberry, and blackberry species	(F)	(M)				(W)
" parviflorus	western thimbleberry	C	F	N	R		WY
Salix spp.	willow species	(F)	(M)				(W)
" bebbiana	Bebb willow	C	F	N			Z
" interior (S. exigua ssp. interior)	sandbar willow	C	F	N	R		Z
Sambucus spp.	elder (elderberry) species	(F)	(M)	(O)			(W)
" cerulea (coerulea)	blueberry elder	C	F	MNO	Q		WY
Sarcobatus vermiculatus	black greasewood	C	F	N	PQ$		WX
Shepherdia (Lepargyrea) argentea	silver buffaloberry (bullberry)	C	F	MNO	RS		WXY
" argentea v. xanthocarpa	silver buffaloberry /yellow-fruited variety/	C	F	MNO	RS		WXY
" canadensis	russet (Canadian) buffaloberry, (rabbitberry)	C	F	NO	QS		WXY
Sorbus scopulina	Greenes mountainash	C	F	NO	Q		Y
Symphoricarpos spp.	snowberry and coralberry species	(F)	(M)	(O)			(W)
" albus	common snowberry	C	Hf	NO	R		WY
" occidentalis	western snowberry, (wolfberry, buckbrush)	C	F	MN	R		WY
Toxicodendron (Rhus) radicans	western poisonivy	C		MN	PR	U	Y
Viburnum spp.	viburnum species	(F)	(M)	(O)			(W)
" lentago	nannyberry viburnum, (black haw, sheepberry)	C	F	O	Q		WY
Vitis riparia	riverbank grape	C	F	N			VWY

Trees

Acer negundo (Negundo aceroides)	boxelder	C		N	QST	WY	
Betula papyrifera	paper (canoe) birch	C		NO	Q T	Y	
Fraxinus pennsylvanica v. lanceolata	green ash	C		N	QS	XZ	
Juniperus scopulorum	Rockymountain juniper	C	F	N	QS	WX	
Pinus ponderosa v. scopulorum	Rockymountain ponderosa pine (bull pine)	C	Hf	NO	Q T	WX	
Populus spp.	poplar (cottonwood) and aspen species	(F)	(M)	(O)			(W)
" sargenti (P. deltoides v. occidentalis)	Plains poplar (cottonwood)	C		N	QRS	XZ	
Populus tremuloides	quaking aspen	C	Hf	NO	QR	WY	
" trichocarpa	California (black) poplar (cottonwood)	C		N	QR	WY	
Salix spp.	willow species	(F)	(M)				(W)
Sorbus scopulina	Greenes mountainash	C	F	NO	Q	Y	
Ulmus americana	American elm	C		N	Q T	WXZ	

The following additional species are known to be present in the Crow Ceded Area. (15)

Grasses

Elymus macouni	Macoun wildrye	CD		K N	Q	X	
Sporobolus cryptandrus	sand dropseed	C	F	K N	Q	X	#

Grasslike plants

Eleocharis spp.	spikesedge species						(W)

Leguminous forbs

Astragalus dasyglottis (agrestis)	purple milkvetch	C		NO		Y	
" missouriensis	/no SPN/ Missouri milkvetch	CDF		NO	Q		
" purshi	Pursh loco or milkvetch (woollypod milkvetch)	C		NO	Q	X	
Oxytropis (Aragallus) sericea	silky (whitepoint) crazyweed	C		NOPQ		Y	

Other forbs (including some half-woody species)

Allium textile	textile (white) onion	C F		MN Q		X
Androsace septentrionalis	/no SPN/ northern androsace	A		N Q		
Antennaria rosea	rose pussytoes	C F		NO		Y
Artemisia biennis	biennial wormwood (sagebrush)	B		MN Q	U	W
Besseya wyomingensis	Wyoming kittentails	C		N		
Calochortus apiculatus	/no SPN/ pointed (Bakers) mariposa	C		NO Q		X
Camelina microcarpa	littlepod (smallseeded) falseflax	AE	Iv	PQ	U	WY
Chenopodium album	lambsquarters goosefoot	AEF	Iv	Q	U	WY
Chorispora tenella /not in SPN/	chorispora (bluemustard)	AE		Q	U	X
Descurainia (Sophia) pinnata	pinnate tansymustard	AEF	Iv	N PQ	U	
Erigeron pumilus	low fleabane	C		NO Q		WX
Eriogonum umbellatum	sulfur eriogonum	C		N		
Eriophyllum lanatum	woolly eriophyllum	C		N		XY
Erodium cicutarium	alfileria (storksbill, heronsbill)	ABEF		M Q	*U	WX
Euphorbia robusta	robust euphorbia	C		N		Y
Gilia (Collomia) linearis	slenderleaf (pink) gilia, (narrow-leaved collomia)	A	Iv	N Q	U	X
Lepidium perfoliatum	clasping pepperweed	AE	Iv	Q	U	
Phlox kelseyi	Kelsey phlox	C		NO QS		Y
Plantago spp.	plantain species	(F)		(M)		(W)
Townsendia hookeri (mensana)	Hookers townsendia	C		NO Q		
Zigadenus venenosus	meadow deathcamas	C		MNOPQ		XY

SELECTED REFERENCES FOR APPENDIX F.

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APPENDIX G WILDLIFE INVENTORY

A. Animals

1. Black bear
2. Raccoon
3. Badger
4. Coyote *
5. Mountain lion
6. Bobcat
7. Prairie dog *
8. Chipmunk
9. Red squirrel
10. Pocket gopher *
11. Mouse (species)
12. Jackrabbit *
13. Cottontail *
14. Elk
15. Mule deer *
16. Whitetail deer *
17. Pronghorn antelope *

B. Reptiles

1. Short horned lizard *
2. Blue racer
3. Gopher snake
4. Rattlesnake

C. Birds

1. Ducks (species)
2. Red-tailed hawk *
3. Golden eagle *
4. Bald eagle
5. Prairie falcon (t) *
6. American kestrel *
7. Grouse (species)
8. Sharp-tailed grouse *
9. Sage grouse
10. Ring necked pheasant
11. Hungarian partridge
12. Mourning dove
13. Belted kingfisher *
14. Flicker *
15. Swallow (species)
16. Black-billed magpie *
17. Crow
18. White-breasted nuthatch *
19. Robin *
20. Mountain bluebird
21. Western meadow lark *
22. Blackbird (species)
23. Pine siskin *
24. Lark bunting

(t) Threatened species
* Personal observation

Table taken from Soil and Range Resources Inventory, East of Little Bighorn River, Crow Indian Reservation, Montana, 1971, BIA.

APPENDIX H FISH SPECIES FOUND IN THE PROPOSED MINING AREAS

A. Fish Species

	Common Name	Scientific Name
1.	Rainbow trout	Salmo gairdneri
2.	Brook trout	Salvelinus fontinalis
3.	Brown trout	Salmo trutta
4.	Cutthroat trout	Salmo clarki
5.	White sucker	Catostomus commersoni
6.	Mountain sucker	Catostomus platyrhynchus
7.	Lake chub	Couesius plumbeus
8.	Longnose dace	Rhinichthys cataractae
9.	Northern pike	Esox lucius
10.	Carp	Cyprinus carpio

APPENDIX I

TABLE OF GEOLOGIC FORMATIONS AND THEIR WATER BEARING CHARACTERISTICS

System	Stratigraphic Unit		Thickness (Feet)	Character and Distribution	Water-bearing Characteristics
Quaternary	Alluvium		0-40±	Detrital material along streams; derived from adjacent upland areas. Includes lenticular beds of clay, sand, and gravel, and mixtures of these.	Gravelly beds in valleys of perennial streams are likely to produce adequate water for stock and domestic supplies. Water is hard, may contain excessive magnesium sulfate.
	Slopewash		0-20±	Detritial material at base of slopes and above flood-plain areas; generally poorly sorted. Rare well-sorted sand or gravel lenses may be present.	Less likely to yield adequate water for domestic or stock uses than alluvium; clean sand or gravel beds may provide small supplies. Quality of water variable.
Tertiary Lower Eocene	Wasatch Formation		0-350±	Clay, sandstone, and coal beds. Limited to higher elevations in southern part of Wolf Mountains.	Water may be obtained from sandstone or coal beds, clinkered surface material may serve as reliable reservoir for small springs or wells. Quality of water not known, probably similar to that from Tongue River Member of Fort Union Formation.
Paleocene	Fort Union Formation	Tongue River Member	0-1,680	Beds of sandstone, shale, shaly sandstone and coal. Few beds are persistent over several square miles.	Water is obtainable from sandstone and coal beds, wells and springs may yield as much as 50 gpm, normally will yield less than 5 gpm. Water from shallow depths usually hard; deeper water is more likely to be soft.
		Lebo Shale Member	100-300	Dark shale, bentonite, with minor sandstones and local thin coal beds.	Wells likely to be dry or to yield meager supplies of highly mineralized water, unfit for stock or household use.
		Tullock Member	300±	Sandstone, coal, and shale beds	Sandstones generally will yield water adequate for stock or domestic supplies. Water quality probably similar to that from the Tongue River Member.
Cretaceous	Hell Creek Formation		600-650	Massive sandstones, sandy shales	Water-bearing characteristics similar to those of Tullock Member of Fort Union.
	Montana Group	Bearpaw Shale	500-600	Primarily dark shale; local sandstone stringers included in southern part of area.	Generally dry; sandstone stringers may contain water too highly mineralized for use.
		Parkman Sandstone	250-350	Shale, sandy shale, and massive sandstone beds; local coal bed near top in southern part of reservation.	Yields small supplies of water; in Crow Reservation coal area quality may be marginal to unusable
		Claggett Shale	350-650	Dark shale; includes sandstone or conglomerate about 140 feet above base.	Generally dry.
		Eagle Sandstone	100-225	Thin sandstone and sandy shale beds.	Contains highly mineralized sodium chloride type water.
		Telegraph Creek Formation	320-850	Sandy shale and thin sandstone.	Contains highly mineralized sodium chlorine type water.
	Colorado Group	Niobrara Shale	400±	Limy shale; includes bentonite beds.	Generally dry; water unfit for stock or household use.
		Carlile Shale	300-425	Shale, bentonite, and concretions.	Generally dry; water unfit for stock or household use.
		Frontier Formation	400±	Shale, bentonite, and thin conglomeratic sandstones.	Generally dry; water unfit for stock or household use.
		Mowry Shale	200-400	Siliceous shale, shale, and bentonite.	Generally dry; water unfit for stock or household use.
		Thermopolis Shale	400-800	Shale and interbedded sandstone and sandy shale.	Generally dry; water unfit for stock or household use.
	Cloverly Group		320-425	Sandstone, sandy shale, clay; includes conglomerate at base.	Some oil test holes have tapped artesian water under sufficient pressure to flow at surface. Water may contain natural gas and petroleum. Water too saline for most uses.
Jurassic	Morrison Formation		140-400	Clays with sandstone and sandy shale strata near base.	Usually not an aquifer.
	Sundance Formation		400-680	Sandstone, sandy shale; limestone at base.	Sandstone yields fairly large supplies of water of marginal quality.
Triassic and Permian (?)	Chugwater Formation		450-655	Sandstone, sandy shale, limestone, gypsum beds.	Poor source of water.
Carboniferous Pennsylvanian	Tensleep Sandstone		45-100	Coarse-grained, cross-bedded sandstone.	Excellent aquifer in parts of Crow Reservation; water likely to be gypsiferous. Large flows near Bighorn and Pryor Mountains.
	Amsden Formation		155-365	Shale, limestone, limy shale, and sandstone.	Excellent aquifer where fractured and cavernous. Water likely to be gypsiferous. Large flows near Bighorn and Pryor Mountains.
Mississippian	Madison Limestone		1,000±	Massive white to light-gray limestone.	Excellent aquifer where fractured and cavernous. Water likely to be gypsiferous. Large flows near Bighorn and Pryor Mountains.
Devonian			0-400	Dolomite and dolomitic shale	Unknown
Silurian	Interlake		0-23	Limestone and dolomite	Unknown
Ordovician	Bighorn - Red River		300±	Massive dolomite, thin basal sandstone, and limestone	Oil test nearby produced 480 barrels per day "fresh water."
Cambrian	Deadwood Formation		900±	Sandstones, shales, and limestones	Unknown.
Precambrian				Granite	Unknown.

APPENDIX J

RECORD OF SELECTED WELLS ON OR NEAR CROW COAL RESOURCE AREA

Location	Owner	Yr. Drilled	Depth ft.	Dia.	Use*	Land Surface Altitude	Depth to Water ft.	Geol. Unit*	Yield gpm
1N 37E 15BBCA	Leo Farley	1971	140	-	H	3,255	16	TLTR	10
1N 37E 27BDCB	Westmoreland Resources	-	30	-	U	3,345	9	Qal	-
1N 38E 31CCCC	George Crum	-	165	-	H	3,534	70	TLTR	-
1S 38E 03CACC	Merle Cox	-	180	-	S	3,652	80	TLTR	-
1S 38E 09BADD	George Crum	1964	80	-	H	3,505	-	TLTR	20
2S 40E 09CAD	---	-	112	4	S	3,415	49	TLTR	-
3S 38E 36BDD	L.O. Mouse	1962	52	6	H	3,440	-	Qal	-
3S 45E 07CCB	NPRR	1968	6,497	-	T	3,125	-	KIMU	-
3S 46E 08BDD	Anschutz #1	1956	3,601	-	T	3,370	-	KJr,Kea	
4S 39E 16BDB	A.E. Dahle	1952	80	4	S	3,660	60	TLTR	8
4S 45E 28AA	Hose-Austin	1957	3,650	-	T	3,168	-	KJr	-
6S 39E 25ACD	R.W. Jordan	1930	54	4	S	4,375	51	TLTR	10
7S 39E 22BCA	C. Penson	1961	42	6	S	4,220	20	Qal	20
9S 39E 16CA	Farmers Union	1965	6,034	-	T	4,132	-	Kea	-

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*Explanation:
Qal = Quaternary Alluvium
TLTR = Tertiary - Lower Tongue River Member
KJr = Cretaceous - Judith River Formation
Kea = Cretaceous - Eagle Sandstone
KIMU = Cretaceous -

Use of Water:
H = Household
S = Stock
T = Oil Test
U = Unused

APPENDIX K

CHEMICAL QUALITY OF GROUND WATER
FROM SELECTED WELLS AND SPRINGS ON OR NEAR CROW COAL RESOURCE AREA
(IN MILLIGRAMS PER LITER, EXCEPT AS INDICATED)

Well Number	Date of Collection	Depth of Well	Aqui-fer	(SiO_2)	(Fe) µg/l	(Ca)	(Mg)	(Na)	(K)	(HCO_3)	(CO_3)	$CaCO_3$	(SO_4)	(Cl)	(F)	(NO_3)	(B) µg/l	Dis-solved Solids Total	Hardness as $CaCO_3$ Total	(SAR)	(Micro-mhos at 25°C)	pH	Temper-ature (°C)	Color
1S-38E-03CACC	--	180	TLTR	-		53	64	22	-	358	-	293	145	-	-	-	-	659	399	-	733	7.5	-	-
1S-38E-09BADD	--	80	TLTR	-	6200	82	96	62	-	433	-	355	364	-	-	-	-	1066	604	-	1230	7.1	-	-
2S-41E-31ACB	10/26/67	168	TLTR	8.5	-	6.3	.8	318	1.6	571	0	-	206	3.2	.5	.4	110	844	19	32	1290	8.1	12	6
3S-38E-36BDD	10/5/67	52	Qal	13	-	54	31	36	2.6	336	0	-	57	2.3	.2	.2	110	361	262	1.0	610	7.7	16	3
3S-45E-07CCB	7/26/68	6,492	KIMU	4.4	-	24	15	1860	64	1120	0	-	1200	1390	2.8	.3	1700	5580	124	73	7660	8.2	-	7
3S-46E-08BDD	7/16/56	3,021 1/	KJr	-	-	20	12	2470	-	465	109	-	0	3490	-	-	-	6650	-	-	-	9.0	-	-
3S-46E-08BDD	7/16/56	3,601 1/	Kea	-	-	48	29	5630	-	965	59	-	23	8210	-	-	-	14200	-	-	-	8.7	-	-
4S-45E-28AA	7/9/57	2,999 1/	KJr	-	-	353	77	1420	-	980	0	-	67	2420	-	-	-	7950	-	-	-	6.8	-	-
7S-40E-29DAA	1/23/69	Spring	TLTR	31	-	60	43	21	10	268	0	-	161	2.6	1.0	5.4	140	483	327	.5	712	8.1	11	2
9S-39E-16CA	2/19/65	5,706 1/	Kea	-	-	10	3	1890	-	2020	0	-	20	1750	-	-	-	4670	-	-	-	7.8	-	-
1N-37E-15BBCA	--	140	TLTR	-	-	6	2	564	-	670	-	661	635	-	-	-	-	1919	22	52	2320	7.1	-	-
1N-37E-27BDCB	--	30	Qal	-	-	52	59	458	-	265	-	218	1103	-	-	-	-	1964	377	-	2430	7.4	-	-
1N-38E-31CCCC	--	165	TLTR	-	-	45	43	244	-	420	-	360	445	-	-	-	-	1225	290	-	1470	7.4	-	-

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1/ Sample depth

APPENDIX L

APPROPRIATIONS BY STREAMS OF WATERS WITHIN THE EASTERN PORTION OF THE CROW INDIAN RESERVATION

STREAM	NO. OF FILINGS	AMOUNT-cfs
Big Horn River	20	86,449.88
Beauvais Creek	4	20
North Beauvais Creek	1	5
South Beauvais Creek	1	5
Buster Creek	1	2
Middle Buster Creek	1	3
Muddy	2	11
Dry Head Creek	2	14.75
Grapevine Creek	8	76.5
Gold Springs	1	.5
Lime Kiln Creek	3	7.75
Rotten Grass Creek	17	81.75
A Spring Draw	1	7.5
Soap Creek	9	133.62
West Soap Creek	1	4
Spring Creek	4	5.05
Warman Creek	2	2.5
Whitman Coulee	2	17.5
Williams Creek	3	68.75
Total Big Horn River & Tributaries	83	86,916.05
Little Big Horn River	37	1,161.116
Alkali Creek	1	1.5
Alligator Creek	2	2.5
John Bozeman Creek	1	1.25
Brush Coulee	3	all
Good Luck Creek	2	7.0
Lodge Grass Creek	13	234.395
Perchan Creek	3	22.3
Unnamed Coulees	1	all
Spring Creek	1	10
Willow Creek	2	13.5
Pass Creek	7	42
Gay Creek	2	3.75
Grey Blanket	3	6.75
West Pass Creek	4	13.5
East Pass Creek	1	5
Spring Water Slough	1	.85
Twin Creek	2	10
Owl Creek	7	45.3
Bartz Creek	1	3.85
Bear Creek	3	30
Bear Creek (Spring Cr.)	1	2
Dry Beaver Creek	2	8

Appendix L (cont.)

Appropriations by Streams of Waters Within the Eastern Portion of the Crow Indian Reservation

STREAM	NO. OF FILINGS	AMOUNT-cfs
Glenn Creek	1	2.5
Kidd Creek	4	12
Little Bear Creek	2	50
Little Owl Creek	6	18.37
Vance Creek	1	4
Reno Creek	3	7.5
South Fork Reno Creek	3	4.55
Shavings Creek	1	.87
Spring Creek	2	7.25
South Fork Squaw Creek	3	all
Waste of Old CB&Q (BN)R.R.Tank	1	1
Total Little Big Horn River and Tributaries	127	1,571.85
Rosebud Creek		
Corral Creek	5	11.9
North Fork Rosebud	1	50
South Fork Rosebud	1	2
Spring Creek	2	7.75
Thompson Creek	3	265
No. Fork Thompson	1	2.5
Total Rosebud Creek and Tributaries	13	338.65
Tongue River		
Squirrel Creek	1	10
Youngs Creek	3	6.75
Total Tongue River & Tributaries	4	16.75
Tullock Creek		
East Tullock Creek	1	.62
Spring Coulee	1	all
Total Tullock Creek and Tributaries	2	.62

Appendix L (cont.)

Appropriations by Streams of Waters Within the Crow Ceded Area

STREAM	NO. OF FILINGS	AMOUNT-cfs
Sarpy Creek		362.79
Spring Creek	1	30.00
Franklin Coulee	2	10.00
West Fork Sarpy	1	5.00
East Fork Sarpy	6	103.00
Cox Coulee	1	5.00
Rainwater Coulee	1	5.00
Unnamed Coulee	1	5.00
South Beaver Creek	2	10.00
Unnamed Coulees	3	50.00
East Bear Creek	2	30.00
Unnamed Creek	3	50.00
Corral Creek	1	25.00
Unnamed Coulee	1	5.00
Koskie Creek	1	25.00
Unnamed Creek	2	.46
Butte Creek	1	5.00
Tullock Creek		159.50
Upper Tullock Creek (Twps. 1S, 1N.)	3	10.00
Upper Tullock Creek (Twp. 1S, Rge. 36E)	2	All [1/]
Middle Tullock Creek (Twps. 2N, 3N)	4	67.50
Lower Tullock Creek (Twp. 4N)	9	82.00
Lower Tullock Creek (Twp. 4N, Rge. 35E)	1	50 AF [2/]

[1/] Allocation of all waters above this point were made. However, since no specific amount was appropriated, the total for Tullock Creek does not reflect this appropriation.

[2/] Allocation of 50 acre feet not included in total.

APPENDIX M

BIG HORN RIVER WATER ALLOCATIONS, CRITICAL PERIOD OF STUDY (31 MONTHS), JULY 1, 1959, THROUGH JANUARY 31, 1962.

		Acre-feet (1,000)		
		Total	Wyoming	Montana
Water supply - 1950 development		3,834.1		
Effective storage drawdown: Boysen		446.2		
Big Horn Lake 1/		224.9		
Gross available water supply		4,505.2		
Non-compact water used or reserved		782.3		
Post 1950 development	175.9			
Future Riverton Project depletion	23.0			
Reserve to Indian lands:				
Wyoming	183.9			
Montana	253.2			
Future supplemental irrigation	90.0			
Senior downstream water rights	56.3			
Net water for compact allotment		3,722.9	2,978.3	744.5
Assignments for new developments		569.3	511.6	57.7
Hanover-Bluff, Wyo.	67.4			
Private development: Wyo.	32.3			
Polecat Bench, Wyo.	174.8			
Shoshone Extensions South, Wyo.	205.0			
Greybull Flat, Wyo.	20.5			
Big Horn Unit, Wyo.	11.6			
Off Reservation:				
Hardin Bench, Mont.	57.7			
Net water available for other uses		3,153.6	2,466.7	686.8
Annual		1,220.7	976.6	244.1
Current available for option contracts		775.0	547.0 2/	228.0
Reserved but not fully available		445.7	429.6	16.1

1/ Drawdown is to 734.2 which reduces power plant capability. Ineffective releases total 115.9.

2/ Boysen 135.0 and Big Horn Lake 412.0.

APPENDIX N

INDUSTRIAL WATER MARKETING SUMMARY EXECUTED CONTRACTS (IN 1,000's OF ACRE-FEET) 1/

Contractor	Date of Contract	Area of Use				
		Wyoming	Montana		Other	
			Non-Indian	Indian		Total
Yellowtail Unit						
Kerr-McGee Corp.	11- 9-67	50[2/]				50
Shell Oil Company	11-22-67		28[2/]			28
Exxon Corporation 3/	12-14-67		50[2/]			50
Peabody Coal Co.	5-24-68		40			40
Reynolds Mining Co.	6-19-69	50				50
John S. Wold 4/	6-20-69	50				50
Gulf Oil Corporation 5/	1-20-70	25				25
Gulf Oil Corporation 5/	3- 2-70			50		50
Peabody Coal Co.	5-22-70			40		40
Colo. Interstate Gas Co.	9- 4-70	30				30
Ayrshire Coal Co.	1-20-71	30				30
Panhandle Eastern Pipeline Co.	1-11-71	30				30
Shell Oil Company	2-10-71			20		20
Norsworthy & Reger, Inc.	4-21-71	50				50
Cardinal Petroleum Co.	5- 7-71	50				50
Subtotal - Yellowtail Unit		365	118	110		593
Westmoreland Resources 6/ (Agricultural Water Transferred)	3- 1-71				30	30
Boysen Unit						
Sun Oil Company	8-15-69	35				35
Mobil Oil Corporation	7/	50				50
Subtotal - Boysen Unit		85				85
TOTAL - Both Units		450	118	110[8/]	30	708

1/ Revised September 25, 1973

2/ Kerr-McGee, Exxon, and Shell contracts do not specify State for intended use. Based on coal resource explorations, it is expected water will be used as shown.

3/ Humble Oil Co. was merged into Exxon Corporation on Jan. 1, 1973.

4/ Contract with "International Geomarine Corp." assigned to Coal Conversion Corp. on 7-13-70 has now been assigned to John S. Wold on 8-25-71.

5/ Gulf Mineral Resources was merged into Gulf Oil Corporation on December 31, 1971.

6/ Contract with Norsworthy & Reger, Inc., assigned to "Westmoreland Resources", 7-22-71.

7/ Signed by Mobil but pending approval by U.S. for final execution.

8/ The Crow Tribe has an allotment of 110,000 AF in the active storage of Yellowtail Reservoir.

Appendix O

TWO MINES PRODUCING FIVE MILLION TONS OF COAL PER YEAR MANNING TABLE (MONTANA)

Personnel	Total
PRODUCTION AND MAINTENANCE: 3 SHIFTS PER DAY, 7-1/4 HOURS PER SHIFT, 5 DAYS PER WEEK, 48 WEEKS PER YEAR (For each of the two 5 million ton mines.)	
Driller	18
Powderman	6
Loader operator	3
Truck driver, over 7-ton	9
Electrician	3
Motor grader operator	3
Crusher operator	3
Tippleman	3
Mechanic	6
Greaser-oiler	3
Labor, unclassified	6
1 SHIFT PER DAY, 7-1/4 HOURS PER SHIFT, 5 DAYS PER WEEK, 48 WEEKS PER YEAR	
Truck driver	1
Scraper operator	2
Dozer operator	2
Mechanic	4
Mechanic helper	2
Hostler	1
3 SHIFTS PER DAY, 8 HOURS PER SHIFT, 6 DAYS PER WEEK, 48 WEEKS PER YEAR	
Dragline operator	3
Weekdays[1]	-
Saturdays[2]	-
Dragline oiler	3
Weekdays[1]	-
Saturdays[2]	-
Dozer operator	3
Weekdays[1]	-
Saturdays[2]	-
Subtotal	84

Personnel	Total
SUPERVISION: 8 HOURS PER DAY, 5 DAYS PER WEEK, 48 WEEKS PER YEAR	
Superintendent	1
Assistant superintendent	1
Mine engineer	1
Assistant mine engineer	1
Office manager	1
Clerk	1
Warehouseman	1
Mine foreman	3
Master mechanic	1
Subtotal	11
Grand total	95

[1] 720 man-shifts per year (3 shifts per day, 240 days).
[2] 144 man-shifts per year (3 shifts per day, 48 Saturdays).

Approximate average salary $13,571

Source: U.S. Bureau of Mines Circular/1972 IC 8535.

APPENDIX P

PERSONNEL REQUIREMENTS AND DIRECT SALARY COSTS

A. Supervisory and Staff Position	1972 Salary Each	Number Required	Total Salary
Complex Superintendent	$25,000	1	$ 25,000
Secretary	7,500	1	7,500
Manager Operation	20,000	1	20,000
Operations Engineer	19,000	3	57,000
Clerk	7,500	1	7,500
Secretary	7,000	1	7,000
Area Engineer	17,000	10	170,000
Area Foreman	15,000	30	450,000
Manager Technical	20,000	1	20,000
Technical Supervisor	19,000	1	19,000
Technical Service Engineer	19,000	5	95,000
Specialist Engineer	19,000	5	95,000
Clerk	7,500	1	7,500
Secretary	7,000	1	7,000
Chief Chemist	16,000	1	16,000
Chemists	14,400	4	57,600
Draftsmen	13,000	3	39,000
Lab Technician	9,500	14	133,000
Maintenance Supervisor	20,000	1	20,000
Clerk	7,500	2	15,000
Secretary	7,000	1	7,000
Maintenance Engineer	18,000	5	90,000
Metal Inspector	17,000	3	51,000
Shop Foreman	17,000	1	17,000
Maintenance Foreman	15,000	8	120,000
Administrative Supervisor	16,500	1	16,500
Personnel Representative	13,500	1	13,500
Asst. Personnel Rep.	12,000	1	12,000
Personnel Clerks	7,500	2	15,000
Training Supervisor	10,000	1	10,000
Office Services Rep.	14,400	1	14,400
Telephone Operators	7,200	2	14,400
Janitors	6,000	2	12,000
Receptionist-Typist	6,000	1	6,000

APPENDIX P

PERSONNEL REQUIREMENTS AND DIRECT SALARY COSTS

A. Supervisory and Staff Position (cont.)	1972 Salary Each	Number Required	Total Salary
Chief Accountant	$ 14,400	1	$ 14,400
Payroll Clerk	7,500	2	15,000
Yield & Shipping Clerks	7,200	3	21,600
Data Processing	11,000	2	22,000
Material Warehouseman	11,700	1	11,700
Purchasing Clerk	7,200	2	14,400
Warehouse Workers	7,500	4	30,000
Secretary	7,000	1	7,000
Security Supervisor	16,500	1	16,500
Safety Foreman	12,500	4	50,000
Nurse	12,500	1	12,500
Security Guard	9,000	6	54,000
		145	$1,936,000

B. Process Operators (Per Shift	1972 Salary Each	Number Required	Total Salary
Operator	$ 10,500	19	$ 200,000
Assistant Operator	9,000	28	252,000
Helper Operator	8,300	11	91,000
Pool Operator	8,000	5	40,000
Overtime @ 4%			23,000
Total Per Shift		63	606,000
Total Process Operators		296	2,850,000

C. Maintenance Mechanics

Lead Plant Repairman	11,200	8	90,000
Plant Mechanic	10,800	81	875,000
Helper Mechanic	8,300	66	548,000
Welder	11,600	19	220,000
Machinist	11,000	16	176,000
Painter	10,000	3	30,000
Electrician	11,000	11	121,000

APPENDIX P

PERSONNEL REQUIREMENTS AND DIRECT SALARY COSTS

C. Maintenance Mechanics (cont.)	1972 Salary Each	Number Required	Total Salary
Communication Tech.	11,000	3	$ 33,000
Corrosion Tech.	10,600	3	32,000
Instrument Tech.	11,000	9	99,000
Pool Laborers	8,000	61	488,000
Overtime @ 6%			161,000
Total Plant Maintenance			$2,873,000
Add: Contract Maintenance			1,447,000
Total Requirements		280	$4,320,000

D. Total Personnel Requirements and Direct Salary Costs

Supervisory and Staff	145	$1,936,000
Process Operators	296	2,850,000
Maintenance Mechanics	280	4,320,000
Grand Total - Schedule C	721	$9,106,000
Average Salary		$ 12,630

APPENDIX Q DUST CLOUD KINETICS

The Turner relationships cited (24) is from an empirical study developed to approximate the concentration of particulate matter from a low level emission at a distance "x" from the source. It was derived for point sources and line sources. Both methods will be analyzed in these pages.

The first method will hold for a point source such as a loader working, or an area source, since an accumulation of point sources will comprise an area source. While each point source will add to the total density of an area source, the particles will only travel a prescribed distance, x, from the source. In other words, while the density is additive, the distance the dust will travel is not.

The method using the line source is given for a check. It more closely parallels the condition of a haul road. This analysis investigates the possibility of a wind perpendicular to a road raising a dust line.

A. Method 1 for a Point Source:

1. The Turner relationship for a point source at ground level is:

$$C_X = \frac{Q}{\pi \times \sigma y \times \sigma z \times u}$$

Where:

C = concentration at a distance from the source

Q = emission rate at the source

σy & σz = horizontal and vertical dispersion coefficients dependent upon distance and air stability and found in charts.

u = wind velocity

2. The equation holds only for very small particles, say below the 50 micron range, which it is assumed will make up a part of the surface of the mine and haul roads. It is further assumed an area of 10 meters square can be treated as a source and that the depth affected on the surface during one second's time is two centimeters. For the worst condition, it is assumed that a very dense cloud will leave the dry, loose surface; say 1,000,000 $\mu g/m^3$.

Therefore: Q = mass per unit time

= volume effected per unit time x mass per unit vol.

= $100 m^2 \times 0.02$ meters/sec. $\times 1 \times 10^6 \mu g/m^3$

= 2,000,000 μg/sec.

3. It is necessary to reach a concentration meeting the EPA standard of 60 $\mu g/m^3$.

Therefore: $C_X = 60 \mu g/m^3$

4. Assume the wind velocity is 20 mph. If it were much greater, turbulance associated with the ground surface and thus dispersion, would also be greater and the dust cloud would break up much quicker (note that the wind velocity appears in the denominator). If it were less, it could never move such a dense cloud.

Therefore: u = 20 mph x 0.447 = 8.94 m/sec.

5. It is necessary to determine how far dust will travel before it disperses to a point at which it meets EPA standards.

Therefore: $$60 \mu g/m^3 = \frac{2{,}000{,}000 \mu g/\text{sec.}}{3.14 \times \sigma_y \times \sigma_z \times 8.94 \text{ m/sec.}}$$

and $\sigma_y \times \sigma_x = \dfrac{2{,}000{,}000}{60 \times 8.94 \times 3.14} = 1187.44\ m^2$

From tables for relatively stable conditions (and therefore less breakup):

For $x = .71$ km,

$\sigma_y = 48.9$ m

$\sigma_z = 24.3$ m

$48.9 \times 24.3 = 1188.27$ very close - use.

6. From the above, it appears that the EPA standard could be met at a distance of 0.71 kilometers from the source or to convert to feet:

$0.71 \times 0.62 \times 5280 = 2324$ feet.

Thus the dust cloud should fall or disperse to meet the EPA secondary standard for particulate matter within one-half mile of the source.

B. Method 2 for a Line Source:

1. The Turner relationship for a line source at ground level is:

$$C_X = \frac{2\,q}{\sqrt{2\pi}\;\sigma_z\,u} \int_{p_1}^{p_2} \frac{1}{\sqrt{2\pi}} \left(e^{-0.5\,p^2} \right) dp$$

Where q = emission rate at the source per unit length

p_1 & p_2 = $\dfrac{y_1}{\sigma_y}$ & $\dfrac{y_2}{\sigma_y}$

y_1 & y_2 = limits of the line, in this case from a point in the center.

Other symbols are the same as listed for Method 1.

2. Assume the mass per unit time for dry loose material leaving the surface will be the same as that assumed for the area in Method 1. Further assume that the length of road is 200 meters.

$$q \quad = \frac{2{,}000{,}000}{200} = \quad 10{,}000 \ \mu g/sec/ft.$$

3. It is necessary to reach a concentration meeting the EPA standard of 60 $\mu g/m^3$.

Therefore: $$C_X \quad = \quad 60 \ \mu g/m^3$$

4. Again assume the wind velocity is 20 mph or:

$$u \quad = \quad 8.94 \ m/sec$$

5. The expression for p_1 and p_2 must be found. Since the length was assumed to be 200 meters, from the center, y_1 and y_2 each equal 100 meters and:

$$p_1 \quad = \quad - \quad \frac{100}{\sigma_y}$$

$$p_2 \quad = \quad + \quad \frac{100}{\sigma_y}$$

6. It is necessary to determine how far dust will travel before it disperses to a point at which it meets EPA standards. Therefore:

$$60 \ \mu g/m^3 \quad = \quad \frac{2 \times 10{,}000}{\sqrt{6.28} \times \sigma_z \times 8.94} \int_{-p}^{+p} \frac{i}{\sqrt{6.28}} \left(e^{-0.5 \ p^2} \right) dp$$

$$\text{or} \ \frac{1}{\sigma_z} \int_{o}^{p} 2 \left(e^{-0.5 \ p^2} \right) dp \quad = \quad \frac{60 \times 6.28 \times 8.94}{2 \times 10{,}000}$$

$$= \quad 0.168$$

Note: $$\int_{o}^{p} \left(e^{-0.5 \ p^2} \right) dp \quad = \quad 0.7064 \int_{o}^{r} \left(e^{-r^2} \right) dr$$

Where $r \quad = \quad 0.7064 \ p$

and $$\int_{o}^{r} \left(e^{-r^2} \right) dr = r - \frac{r^3}{3} + \frac{r^5}{5.2\,!} - \frac{r^7}{7.3\,!} + \text{-----}$$

Therefore:

$$\frac{0.7064 \times 2}{\sigma_z} \int_{0}^{\frac{100}{\sigma_y}} \left(e^{-0.5\, p^2} \right) dp =$$

$$\frac{1.413}{\sigma_z} \left(0.7064p - \frac{(0.7064p)^3}{3} + \frac{(0.7064p)^5}{5.2\,!} - \frac{(0.7064)^7}{7.3\,!} + -- \right) \Bigg|_{0}^{\frac{100}{\sigma_y}}$$

From tables @ $X = .37$ km

$\sigma_y = 27$

& $\sigma_z = 14.5$

which when substituted in the above expression = 0.168

7. Therefore, the EPA standard could be met at a distance of 0.37 kilometers from the source or to convert to feet:

$$0.37 \times 0.62 \times 5280 = 1211 \text{ feet}$$

Using this method, the dust cloud should fall or disperse to meet the EPA secondary standard for particulate matter within one-quarter mile of the source.

APPENDIX R

DETERMINATION OF HEIGHT OF STACK. The method used to determine the height of the stack required for the power generating plants described in these pages is adapted from an analysis contained in Chapter 7 of the Fundamentals of Air Pollution by S. J. Williamson. Since the proposals contained herein are merely possibilities and not actual plans, the analysis has not been rigorous but merely carried far enough to determine whether ground level ambient air standards could be met with sufficiently high exhaust stacks.

1. Basic Equations:

a. Height of Plume

$$X_{max} = \frac{2Q_m}{\pi ueh^2} \frac{Cz}{Cy}$$

where X_{max} = concentration at distance from stack where ground level concentration is at a maximum.

Q_m = emission rate of pollutant

u = wind speed

Cz and Cy = diffusion parameters

e and π = constants (2.718 & 3.1416)

b. Height of Plume Rise above Stack

$$h_r = a \frac{vd_s}{u} + b \frac{Q_h^{\frac{1}{2}}}{u}$$

where h_r = height of plume rise over stack

a & b = constants

V = exit velocity of gases

d_s = diameter of the stack

Q_h = heat emission rate (as thermal energy)

c. Height of Stack

$$h_s = H - h_r$$

where h_s = height of stack

2. Values of Known Quantities

a. X_{max} = most critical E P A ambient air standard

$= 150\ \mu g/m^3$ for particulate matter in 24 hours

$= 260\ \mu g/m^3$ for SO_2 in 24 hours

$= 100\ \mu g/m^3$ for NO_x annual mean (could be exceded briefly)

b. Q_m = emission rate

= million BTUs/hr burned x lbs pollutant/million BTU

(1) Hypothetical Plant which would burn coal

$$\text{BTUs/hr burned} = \frac{5{,}000{,}000 \text{ tons/yr} \times 2000 \text{ lbs/ton} \times 9000 \text{ BTUs/lb}}{365 \text{ day/yr} \times 24 \text{ hrs/day}}$$

$$= 1.027 \times 10^{10} \text{ BTUs/hr}$$

Fly ash emitted = $0.08\ \text{lbs}/10^6$ BTU

SO_2 emitted = $0.84\ \text{lbs}/10^6$ BTU

NO_x emitted = $0.37\ \text{lbs}/10^6$ BTU

Therefore:

$$Q_{m1} = 1.027 \times 10^{10} \times 0.08 \times 10^{-6} \times 1.26 \times 10^{-4}\ \frac{\text{kg/sec}}{\text{lbs/hr}}$$

$$= 0.103\ \text{kg/sec Fly Ash}$$

$$Q_{m2} = 1.027 \times 10^{10} \times 0.84 \times 10^{-6} \times 1.26 \times 10^{-4}$$

$$= 1.086\ \text{kg/sec } SO_2$$

$Q_{m3} = 1.027 \times 10^{10} \times 0.37 \times 10^{-6} \times 1.26 \times 10^{-4}$

$= 0.477$ kg/sec NO_x

(2) Plant @ Complex B Under High Level Development which would burn char

BTUs/hr burned $= \dfrac{9,000,000 \times 2000 \times 6000}{365 \times 24}$

$= 12.329 \times 10^9$ BTUs/hr

Fly Ash emitted = 0.05 lbs/10^6 BTU

SO_2 emitted = negligible

NO_x emitted = 0.37 lbs/10^6 BTU

Therefore:

$Q_{m1} = 12.329 \times 10^9 \times 0.05 \times 10^{-6} \times 1.26 \times 10^{-4}$

$= 0.0777$ kg/sec Fly Ash

Q_{m2} = negligible

$Q_{m3} = 12.329 \times 10^9 \times 0.37 \times 10^{-6} \times 1.26 \times 10^{-4}$

$= 0.574$ kg/sec

c. $\bar{u}$ = wind speed: Assume 10 mi/hr

$\bar{u}$ = 10 mi/hr = 4.4 m/sec

d. $\dfrac{Cz}{Cy} = 0.7$ at ground level (from text)

e. V = exit velocity: Assume 60 mph

V = 60 mph = 100 km/hr = 27.8 m/sec

f. a & b = constants

Values taken from table

$a = -1.04$)
$b = 0.071$) for stable conditions

$a = 0.35$)
$b = 0.084$) for neutral conditions

g. d_s = diameter of stacks: Assume 26 ft. or 8 meters

h. Q_h = heat emission rate

Assume rate at which thermal energy is exhausted up the stack = 6% of rate at which energy is liberated by combustion. Also station heat rate of 9000 BTU/KWH indicates plant is about 40% efficient.

(1) Hypothetical Coal Burning Plant (Size assumed from Figure 4)

$$Q_h = \frac{1,140,000}{.40} \times 0.06 = 171,000 \text{ KW}$$

$$= 171,000,000 \text{ W}$$

$$= 171 \times 10^{6} \text{ J/sec}$$

(2) Plant @ Complex B

$$Q_h = \frac{1,360,000}{.40} \times 0.06 = 204,000 \text{ KW}$$

$$204 \times 10^{6} \text{ J/sec}$$

3. Calculations:

a. Height of Plume

$$X_{max} = \frac{2Q_m}{\pi u e H^2} \quad \frac{Cz}{Cy}$$

$$H^2 = \frac{2Q_m}{ueX_{max}} \quad \frac{Cz}{Cy}$$

(1) For Plant @ Central Mine

(a) For Fly Ash

$$H = \sqrt{\frac{2 \times 0.103 \text{ kg/sec} \times 1000 \text{ g/kg} \times 0.7}{3.14 \times 4.4 \times 2.718 \times 150\ \mu\text{g/m}^3 \times 10^{-6}\ \text{g}/\mu\text{g}}}$$

$$= \sqrt{25,593}$$

$$= 160 \text{ meters}$$

(b) For SO_2

$$H = \sqrt{\frac{2 \times 1.086 \times 1000 \times 0.7}{3.14 \times 4.4 \times 2.718 \times 260 \times 10^{-6}}}$$

$$= \sqrt{155{,}680}$$

= 394 meters

(c) For NO_x

$$H = \sqrt{\frac{2 \times 0.477 \times 1000 \times 0.7}{3.14 \times 4.4 \times 2.718 \times 100 \times 10^{-6}}}$$

$$= \sqrt{177{,}833}$$

= 422 meters

(2) For Plant @ Complex B

(a) For Fly Ash

$$H = \sqrt{\frac{2 \times 0.0777 \times 1000 \times 0.7}{3.14 \times 4.4 \times 2.718 \times 150 \times 10^{-6}}}$$

$$= \sqrt{19{,}326}$$

= 139 meters

(b) For SO_2: Negligible

(c) For NO_x:

$$H = \sqrt{\frac{2 \times 0.574 \times 1000 \times 0.7}{3.14 \times 4.4 \times 2.718 \times 100 \times 10^{-6}}}$$

$$= \sqrt{213{,}890}$$

= 462 meters

b. Plume Rise Above Stack

$$h_r = a \frac{vd_s}{u} + b \frac{Q_h^{\frac{1}{2}}}{u}$$

(1) For Stable Conditions

(a) For Coal Burning Plant

$$h_r = (-1.04)\ \frac{27.8 \times 8}{4.4} + 0.071\ \frac{(171 \times 10^6)^{\frac{1}{2}}}{4.4}$$

$$= -53 + 211 = 158 \text{ meters}$$

(b) For Plant @ Complex B

$$h_r = -53 + 0.071\ \frac{(204 \times 10^6)^{\frac{1}{2}}}{4.4}$$

$$= -53 + 230 = 177 \text{ meters}$$

(2) For Neutral Conditions

(a) For Coal Burning Plant

$$h_r = (0.35)\ \frac{27.8 \times 8}{4.4} + (0.084)\ \frac{(171 \times 10^6)^{\frac{1}{2}}}{4.4}$$

$$= 18 + 250 = 268 \text{ meters}$$

(b) For Plant @ Complex B

$$h_r = (0.35)\ \frac{27.8 \times 8}{4.4} + 0.084\ \frac{(204 \times 10^6)^{\frac{1}{2}}}{4.4}$$

$$= 18 + 273 = 291 \text{ meters}$$

c. Height of Stack

$$h_s = H - h_r$$

(1) For Coal Burning Plant

(a) For SO_2: Since the standard is a maximum concentration for 24 hours only, assume stable conditions are most critical.

$$h_s = 394 - 158 = 236 \text{ meters}$$

$$= 236 \times 3.281 = 774 \text{ feet}$$

(b) For NO_x: Since the standard is a maximum average concentration throughout the year, assume average or neutral conditions.

h_s = 422 - 268 = 154 meters

= 154 x 3.281 = 505 feet

SO_2 value governs

(2) For Plant @ Complex B

(a) For Fly Ash

h_s = 139 - 177 = impossible answer

Therefore, a minimal height stack is needed for fly ash.

(b) For NO_x: as in 3. c. (1) (b) above, assume neutral conditions.

h_s = 462 - 291 = 171 meters

= 171 x 3.281 = 561 feet

Use 560 feet

Conclusion:

When a firm plan is presented, the stack height must be rigorously computed through dispersion modeling. For now, it appears that adjustment of the stack height for either type of plant (coal or char burning) would allow dispersion sufficient to meet EPA standards.

APPENDIX S HYPOTHETICAL REFINERY EMISSION INVENTORY
(Tons/Day)

Source Name	SO_2	Part.	HC	NO	CO
Incinerator	.002	.020	.0	.169	.011
Catalytic Cracker	3.25	.023	.0	2.71	3.6
Flare	.0	.0	.0	.056	.0
Atmospheric Column	.32	.044	.0	.54	.0
Vacuum Column	.16	.031	.0	.27	.0
Catalytic Reformer Htr. 1	.14	.020	.0	.18	.0
Catalytic Reformer Htr. 2	.22	.029	.0	.23	.0
Visbreaker	.13	.026	.0	.22	.0
Power Boiler	.16	.031	.0	.28	.0
Blow Down System	.0	.0	.25	.0	.0
Process Drains	.0	.0	.41	.0	.0
Cooling Towers	.0	.0	.31	.0	.0
Pipe Valves & Flanges	.0	.0	1.41	.0	.0
Vessel Relief Valves	.0	.0	.55	.0	.0
Pump Seals	.0	.0	.71	.0	.0
Compressor Seals	.0	.0	.25	.0	.0
Miscellaneous	.0	.0	.50	.0	.0
Tank Farm	.0	.0	.50	.0	.0
Daily Emission	4.4	.22	4.9	4.66	3.611
Annual Emission	1,606.0	80.3	1,789.0	1,700.0	1,318.0

From Reference (30)

APPENDIX T

AMBIENT AIR STANDARD COMPARISONS
($\mu g/m^3$)

Constituent	OAP/EPA Standards		Hypothetical Refinery Annual Contribution (distance miles)				Allowable Background Standards[1]	
	Primary	Secondary	0.5	1	2	3	Primary	Secondary
Particulates	.75 (annual)	.60	.1	.02	.02	.02	74.9	59.9
SO_2	0.14 (24-hr.)	0.10	0.3	.25	.25	.25	--	--
NO_2	100 (annual)	100	1.0	.5	.25	.01	99	99
CO	10000 (8-hr.)	10000	1	.5	.1	.1	--	--
HC	160 (3-hr.)	160	3.0	2.0	1.3	0.5	--	--

NOTE: Primary standard protects health; secondary standard protects public welfare.

[1] Compared with maximum value

From Reference 30

APPENDIX U

FOREST ACREAGE IN CROW RESERVATION MINING AREA

	TOTAL ACRES IN LEASE/PROSPECT AREA	ESTIMATED TOTAL ACRES FORESTED IN LEASE	PERCENT OF LEASE IN FOREST LANDS	ESTIMATED PRESENT VALUE OF ALL MERCHANTABLE TIMBER PER ACRE
PEABODY	11,211	300	2.7%	$ 90,000
CROW	70,473	9,000	12.7%	$2,700,000
GULF	73,454	12,000	16.3%	$3,600,000
SHELL	30,248	1,030	3.4%	$ 304,000
SUBTOTALS	185,386	22,330	12.0%	$6,694,000 [1/]
CEDED AREA	47,044	9,400	20.0% [2/]	$ 825,000 [3/]
	232,430	31,730	14.0%	$7,519,000

[1/] Based on: 6,000 bd. ft. per acre and $50.00 per thousand board feet (Approximate value being realized in mid-1973.

[2/] Only crude estimates available

[3/] Based on: 3,500 bd. ft. per acre estimated and $25.00 per thousand board feet, estimated mid-1973 values.

APPENDIX V

FORESTLANDS DISTURBED PER YEAR IF ALL DEVELOPMENT OCCURS IN THE WOLF MOUNTAINS
(Ceded Area data unavailable)

	MODEST DEVELOPMENT		INTENSIVE DEVELOPMENT	
	Acres	Value of Timber	Acres	Value of Timber
PEABODY	NO LANDS		NO LANDS	
CROW	66	$19,800	100	$ 30,000
GULF	67	$20,100	200	$ 60,000
SHELL	67	$20,100	200	$ 60,000
TOTALS	200	$60,000	500	$150,000

Appendix W

Low Level:

PROJECTED PLACE OF RESIDENCE OF EMPLOYEES

Community	Indian Direct	Indian Indirect[1]	Non-Indian Direct	Non-Indian Indirect	Total
Hardin	--	--	225	450	675
Lodge Grass [2]	35	--	--	--	35
Little Bighorn Valley [3]	50	--	--	--	50
Sheridan, Wyoming	--	--	--	--	--
Yellowstone Valley [4]	--	--	--	315	315
Northern Crow Reservation [5]	140	--	--	--	140
Total	225	--	225	765	1,215

High Level:

Community	Indian Direct	Indian Indirect	Non-Indian Direct	Non-Indian Indirect	Total Direct	Total Indirect	All
Hardin	75	25	1,448	2,564	1,523	2,589	4,112
Lodge Grass [2]	200	50	315	829	515	875	1,390
Little Bighorn Valley [3]	175	25	340	850	515	875	1,390
Sheridan, Wyoming	30	20	3,347	5,721	3,377	5,741	9,118
Yellowstone Valley [4]	--	25	350	570	350	595	945
Northern Crow Reservation [5]	150	50	75	332	225	382	607
Total	630	195	5,875	10,866	6,505	11,058	17,563

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[1] The employment multiplier that was used was 2.0 locally and an additional 0.7 for the remainder of southeastern Montana and northeastern Wyoming.

[2] Lodge Grass includes the area immediately surrounding the town.

[3] Little Bighorn Valley includes the area from Wyola to Benteen.

[4] Yellowstone Valley includes the area along the Yellowstone River from Billings to Forsyth.

[5] Northern Crow Reservation includes the area along the Little Bighorn from Garryowen to the north reservation boundary near Hardin.